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THE PURPOSES OF TASK 36 ARE TO:

1. COLLECT, ASSEMBLE, AND EVALUATE EXISTING AND NEW GEOTECHNICAL, HYDROLOGIC, AND WATER QUALITY DATA
2. EXAMINE THE COMPONENTS OF THE NORTH BOUNDARY CONTAINMENT SYSTEM
3. EVALUATE RESPONSE ACTIONS WHICH SHOULD INCREASE SYSTEM EFFICIENCY.

THIS TASK WILL FURTHER CHARACTERIZE THE GEOLOGIC REGIME IN THE VICINITY OF THE NBCS. ALSO A HYDROLOGIC EVALUATION WILL BE PERFORMED USING PRIMARILY WATER LEVEL AND QUALITY DATA. THE SCOPE OF WORK INCLUDES DEVELOPMENT, INSTALLATION, AND SAMPLING OF NEW MONITORING WELLS PLUS AN EVALUATION OF THE PHYSICAL CONDITION, INTEGRITY, AND HYDROLOGIC PROPERTIES OF THE BARRIER.

SECTIONS OF THIS PLAN DETAIL PROCEDURES TO BE USED IN THE FOLLOWING PROGRAMS:

1. GEOTECHNICAL INVESTIGATION
2. CHEMICAL ANALYSIS
3. QUALITY ASSURANCE

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LITIGATION TECHNICAL SUPPORT AND SERVICES

ROCKY MOUNTAIN ARSENAL

NORTH BOUNDARY SYSTEM COMPONENT RESPONSE ACTION ASSESSMENT

DRAFT FINAL TECHNICAL PLAN

TASK NUMBER 36

MARCH 1987

ENVIRONMENTAL SCIENCE AND ENGINEERING, INC.

PROGRAM MANAGER'S OFFICE FOR ROCKY MOUNTAIN ARSENAL

LITIGATION TECHNICAL SUPPORT AND SERVICES

ROCKY MOUNTAIN ARSENAL
NORTH BOUNDARY SYSTEM COMPONENT RESPONSE ACTION ASSESSMENT

DRAFT FINAL TECHNICAL PLAN
MARCH 1987
CONTRACT NUMBER DAAK11-84-D-0016
TASK NUMBER 36

ENVIRONMENTAL SCIENCE AND ENGINEERING, INC.
HARDING LAWSON ASSOCIATES

REQUESTS FOR COPIES OF THIS DOCUMENT SHOULD BE REFERRED TO PROGRAM MANAGER, AMXRM ABERDEEN PROVING GROUND, MARYLAND 21010

PREPARED FOR

US ARMY
PROGRAM MANAGER'S OFFICE FOR ROCKY MOUNTAIN ARSENAL

LITIGATION TECHNICAL SUPPORT AND SERVICES

Rocky Mountain Arsenal

North Boundary System Component
Response Action Assessment

Draft Final Technical Plan
March 1987
Contract Number DAAK11-84-D-0016
Task Number 36

PREPARED BY

ENVIRONMENTAL SCIENCE & ENGINEERING, INC.
Harding Lawson Associates

PREPARED FOR

Office of Program Manager
Rocky Mountain Arsenal Contamination Cleanup

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LIST OF ACRONYMS AND ABBREVIATIONS
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AR	Army Regulation
CA	Contamination Assessment
CDH	Colorado Department of Health
cm	centimeters
COE	U.S. Army Corps of Engineers
cpt	cone penetration test
CSEO	Colorado State Engineers Office
DARCOM	U.S. Army Material Development and Readiness Command
DA-PAM	Department of Army Pamphlet
DBCP	dibromochloropropane
DCPD	dicyclopentadiene
DIMP	diisopropylmethylphosphonate
DMMP	dimethylmethylphosphonate
ESE	Environmental Science and Engineering, Inc.
ft	feet
gpd/ft	gallons per day/foot
gpm	gallons/minute
MIBK	methylisobutylketone
MOA	Memorandum of Agreement
NBCS	North Boundary Containment System
OSHA	Occupational Safety and Health Act
PMO-RMA	Program Manager's Office-Rocky Mountain Arsenal

LIST OF ACRONYMS AND ABBREVIATIONS
(Page 2 of 2)

ppm	parts per million
QA	Quality Assurance
QC	Quality Control
RIC	Rocky Mountain Arsenal Resource Information Center
RMA	Rocky Mountain Arsenal
USATHAMA	U.S. Army Toxic and Hazardous Materials Agency
USEPA	U.S. Environmental Protection Agency
WES	U.S. Army Waterways Experiment Station

EXECUTIVE SUMMARY

The North Boundary Containment System (NBCS) was designed to intercept contaminated and potentially contaminated ground water which flow through areas within Rocky Mountain Arsenal (RMA) toward the northern site boundary. The system was designed to treat and recharge this extracted ground water. A pilot containment system was constructed in 1978 and consisted of a 1,500-ft long soil-bentonite barrier, 6 dewatering wells, and 12 recharge wells. The system was expanded in 1981 to the present configuration which includes a 6,740-ft long soil-bentonite barrier, 54 dewatering wells, and 38 recharge wells.

The purpose of this task is to collect, assemble, and evaluate existing and new geotechnical, hydrologic, and water quality data to examine the system components of the NBCS and to evaluate response actions which should increase system efficiency. To accomplish these objectives, this task will further characterize the geologic regime in the vicinity of the NBCS utilizing data from previous investigations and additional data to be collected as part of this task. Where historical data is lacking, additional soil borings will be constructed and soil and rock samples collected. Particular attention will be directed to the areal extent and position of Denver sand units.

In addition to the geologic characterization, a hydrologic evaluation will be performed using primarily water level and quality data. Much of this data is being collected as part of the Regional Water Quality/Water Quantity Survey (Tasks 4 and 44) and the Boundary Systems Monitoring (Task 25) task. To complement the information available from these tasks and fill data deficiencies, the Task 36 scope-of-work includes installation, development, and sampling of new ground water monitoring wells in selected locations. As these new wells are completed and developed they will be sampled for water quality parameters to aid in the identification of other locations for which monitoring wells may provide valuable information and will be sampled in coordination with Task 25 and 44 sampling events to provide an integrated data set.

Using the data described above, an assessment of the hydrologic conditions in the vicinity of the NBCS will be performed. This will include an assessment of both dewatering and recharge components of the NBCS and the hydrologic relationship between saturated portions of the alluvium and the Denver Formation.

To complete the assessment of the NBCS, the Task 36 Scope-of-Work will include an evaluation of the physical condition, integrity, and hydrologic properties of the soil-bentonite barrier. Samples of the barrier will be collected and subjected to both physical and hydrologic testing. This data in conjunction with results of the geologic and hydrologic assessment should allow evaluations of the effectiveness of the barrier.

Upon completion of data assessment, candidate response actions which may enhance system performance will be developed and evaluated. These actions may include physical modification to the NBCS and/or modifications to the NBCS operational procedures. The preferred response actions will be recommended for implementation and categorized as to whether they should be considered as interim of long-term actions.

1.0 INTRODUCTION

The Rocky Mountain Arsenal (RMA) occupies 27 square miles in southern Adams County, Colorado (Figure 1.0-1). It lies within the Denver metropolitan area just north of the City of Denver and just east of Commerce City, Colorado. Since startup in 1942 it has been a site for the manufacture and demilitarization of chemical, incendiary munitions, and the manufacture of industrial chemicals, primarily pesticides and herbicides. A detailed account of disposal practices associated with these operations and an overview of resulting soil and water contamination are presented in the Task 1 Technical Plan (RIC#85127R07).

The disposal practices of the Army and leaseholders took place over a period of 30 years or so and led to the widespread introduction into the ground water of a host of organic and inorganic contaminants; most notably, chloride, fluoride, DIMP, DCPD, DBCP, organosulfur compounds, organochlorine pesticides, volatile aromatic compounds, and volatile organohalogen compounds. Ground water monitoring programs conducted since the mid-1970's have detected some or all of these compounds near or outside the boundaries of RMA.

To curtail migration of contaminants from the North Boundary of RMA, a ground water containment and treatment system was constructed there in two phases, a pilot system in 1978 and an expansion in 1981. The three major components of the system that will be examined in detail are the dewatering/recharge system; the soil-bentonite barrier; and the extent and configuration of Denver sands units near the North Boundary. The objectives of Task 36 are to assess the integrity of the various components of this contamination control system, investigate the hydrogeologic regime and its response to the operation of the system, and propose operational and/or design modifications to response to any problems that might exist.

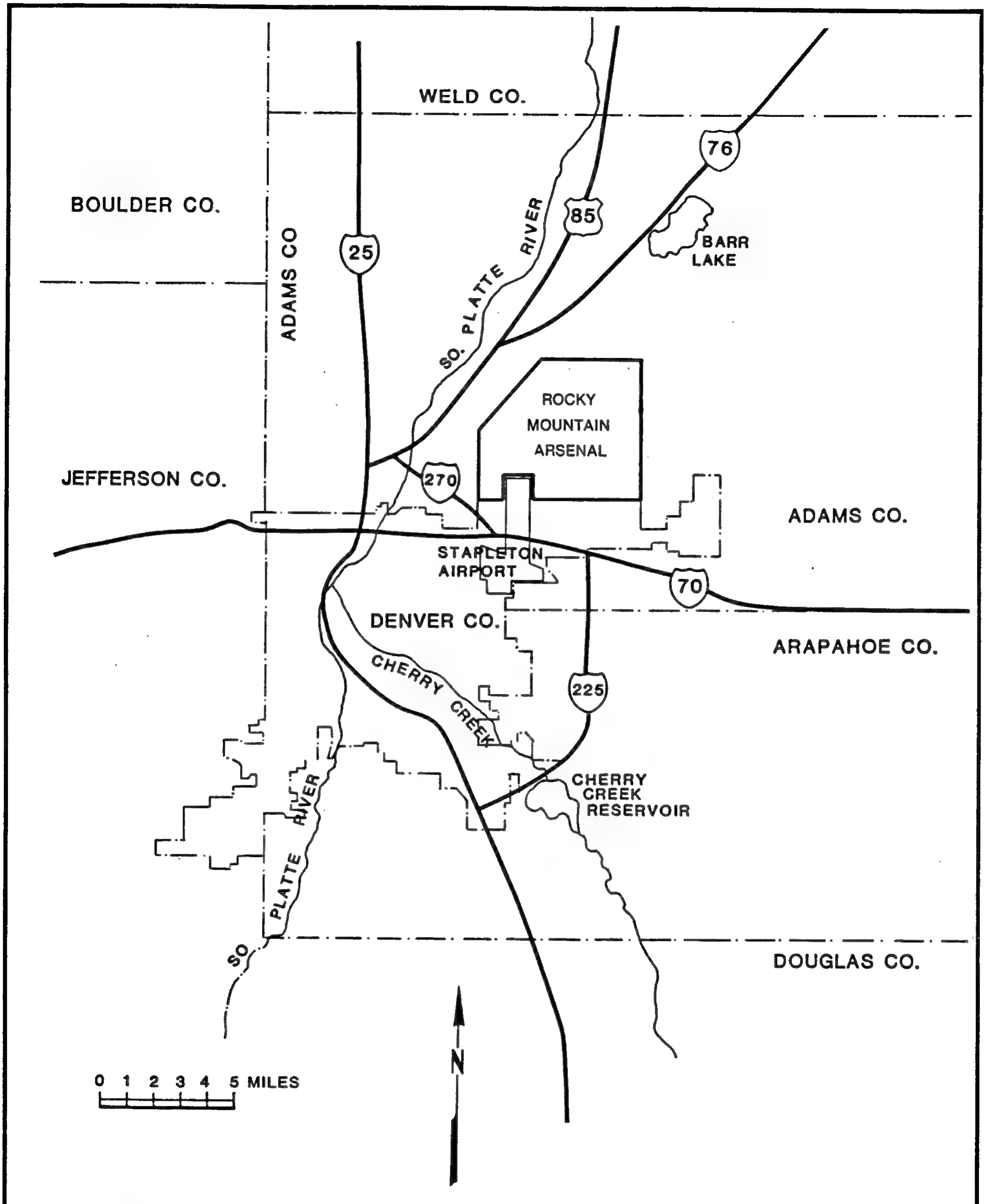


Figure 1.0-1
LOCATION MAP OF
ROCKY MOUNTAIN ARSENAL

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

1.1 STATEMENT OF THE PROBLEM

A comprehensive study conducted in fiscal year 1984 and detailed in the North Boundary Containment/Treatment System Performance Report by Thompson, et al., December, 1985, has outlined the success of the system in:

- o Acting as a barrier to the majority of the contaminated alluvial ground water flow in the area;
- o Effectively removing the organic contaminants from the extracted ground water; and
- o In general reducing contaminant levels downgradient.

That study also identified several problems which need to be addressed:

- o The development of a high [up to 10 feet (ft)] hydraulic head differential across the soil-bentonite wall from the upgradient to the downgradient side;
- o Significant concentrations of some contaminants are still detected north of the system in the offpost area;
- o The inability of the recharging wells to effectively handle all of the treated effluent;
- o Some low levels of contamination have been detected in Denver Formation sandstone units in contact with the alluvium north of the barrier; and
- o An area of possible flow between a Denver Formation sandstone and the alluvial aquifer has been identified below the pilot barrier portion of the slurry wall.

This study will focus on addressing these problems in detail and identifying modifications that will improve the system's effectiveness.

1.2 NORTH BOUNDARY CONTAINMENT SYSTEM DESCRIPTION

The North Boundary Containment System (NBCS) is located about 250 ft south of the north boundary of RMA in Sections 23 and 24 (Figure 1.2-1). It consists of a 6,740-ft-long bentonite slurry wall, a series of 54 ground water withdrawal wells, a carbon-adsorption type water purification plant, and a line of 38 recharge wells.

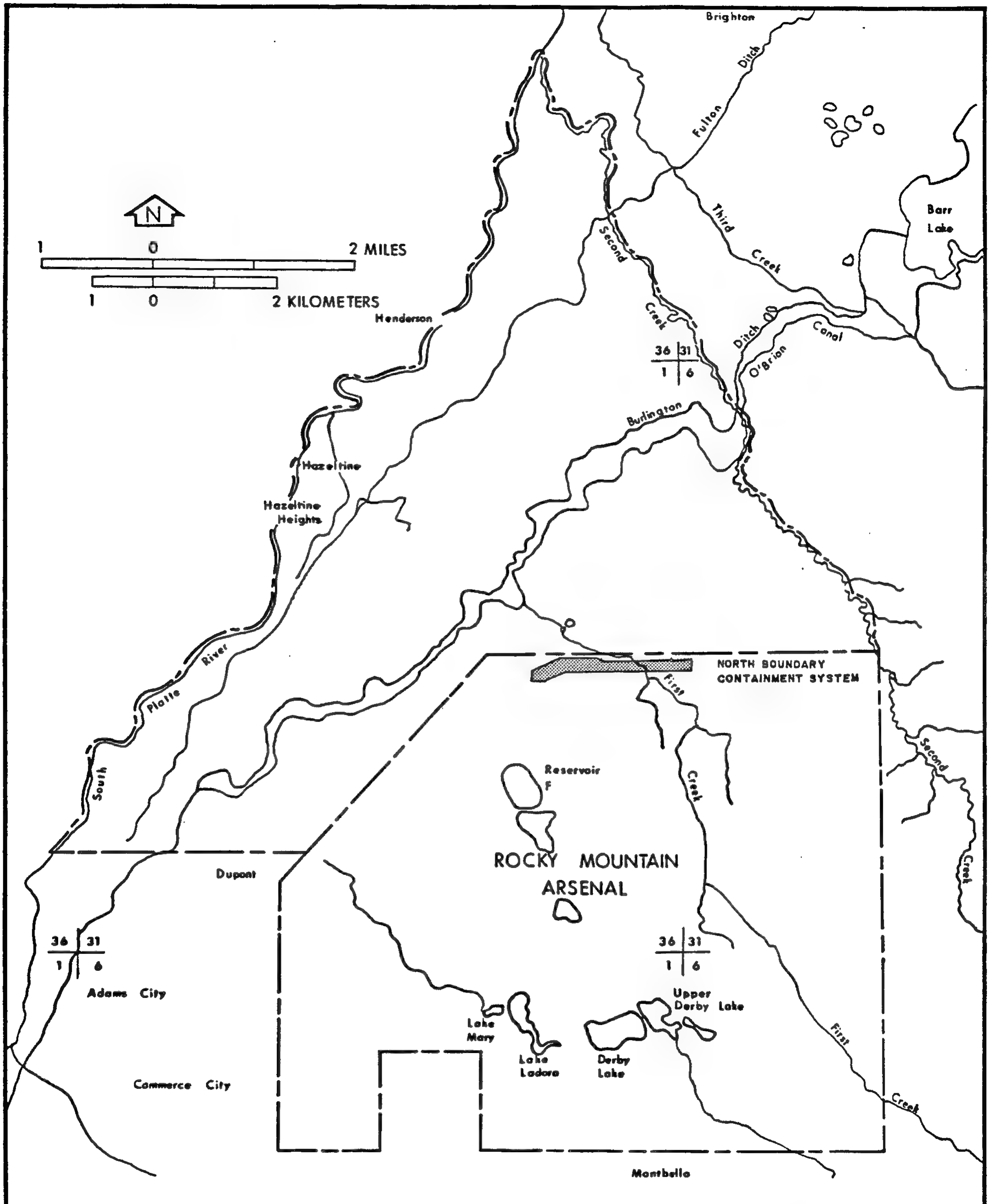


Figure 1.2-1
NORTH BOUNDARY CONTAINMENT SYSTEM LOCATION MAP

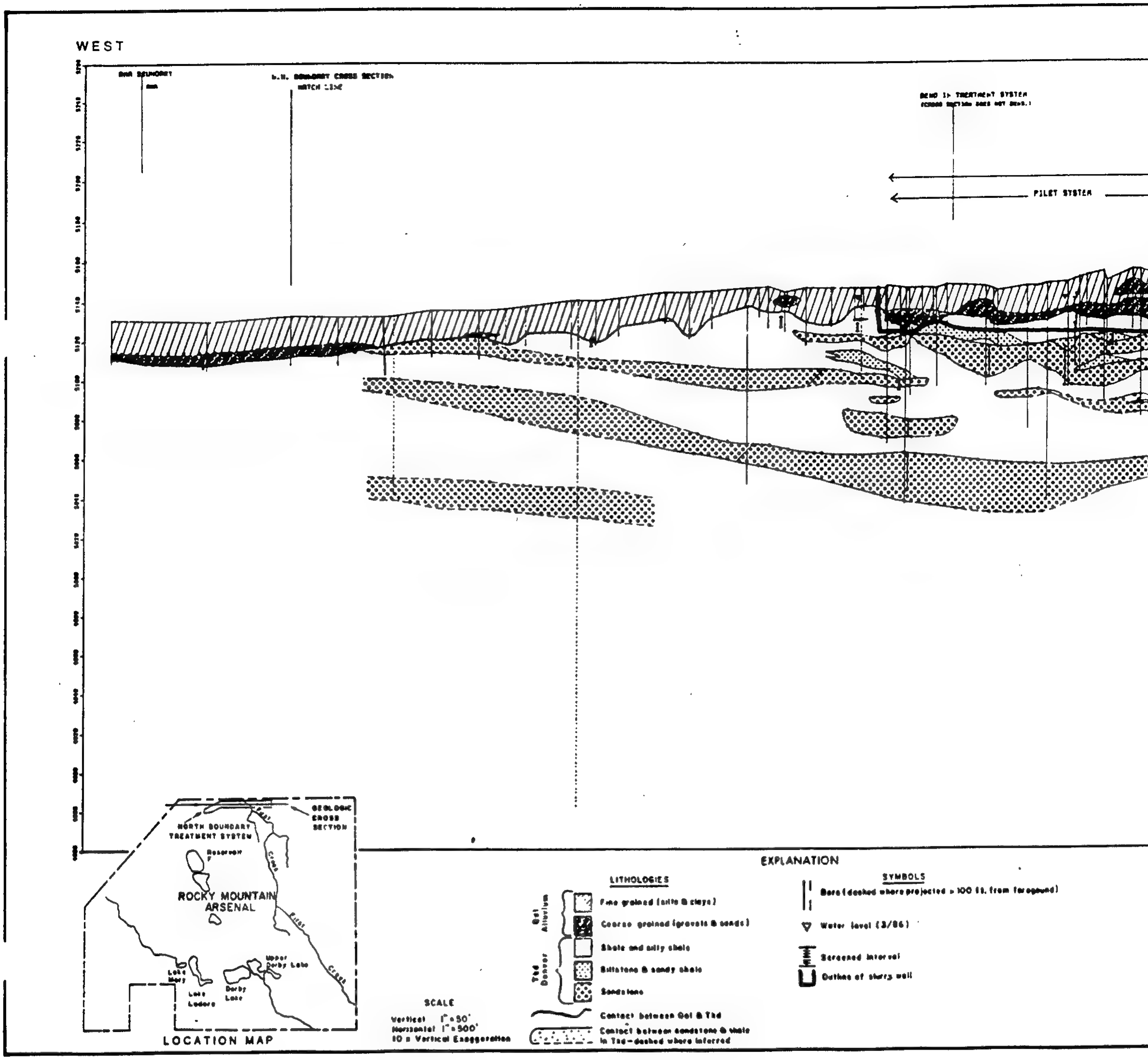
Prepared for:
U.S. Army Program Manager's Office For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

1.2.1 GEOLOGY

Along the North Boundary the geology consists of two major stratigraphic units-the Quaternary alluvium and the Cretaceous-Tertiary Denver Formation. The system extends across a north- to northeast-trending alluvial valley that is incised into the underlying Denver Formation (Figure 1.2-2). The valley is filled with unconsolidated sediments of Holocene Age ranging up to 30 ft in thickness and consisting of a lower unit of sand and gravel averaging about 12-ft thick and an upper unit of silts and clays averaging about 15-ft thick (Figures 1.2-2 and 1.2-3).

The unconsolidated sediments are underlain by the Denver Formation which consists of 210 to 370 ft of olive, bluish gray, green gray, and brown clay, shale, and siltstone interbedded with poorly sorted, weakly lithified tan to brown, fine to medium grained, lenticular sandstone and conglomerate. Lignite beds and carbonaceous shales are common, and to a lesser degree are volcanic fragments, and tuffaceous materials. Minor beds of bentonite may also be present. The predominant olive green-gray colors resulting from erosion and weathering of andesitic and basaltic lavas help distinguish the formation from the underlying lighter colored Arapahoe Formation. The Denver Formation in the area of the NBCS consists of approximately 30 to 40 percent sand and to 60 to 70 percent silt and shale.

Water bearing zones in the formation are restricted to sandstone lithologies that are lenticular in nature. These lenses are irregularly distributed within thick clay-shale sequences. They are discontinuous and therefore difficult to trace, and are poorly defined where sandstones grade into encompassing clay and shale. In the area of the NBCS, sand comprises lenticular to tabular horizons up to 20-ft thick and more than 500-ft long whose three-dimensional configurations and connections are, as yet, poorly understood. It appears that sandstone horizons which are present below the treatment system, project updip to the surface and subcrop to the north of 96th Avenue (Figure 1.2-3). A detailed study of the Denver Sands will be included in the Task 36 System Assessment (Section 8.0).


WEST
PILOT SYSTEM
NORTH BOUNDARY TREATMENT SYSTEM
GEOLOGIC CROSS SECTION
ROCKY MOUNTAIN ARSENAL
Reservoir F
Lake Mary
Lake Ladora
Upper Derby Lake
Derby Lake
First Creek
LOCATION MAP
SCALE
Vertical 1" = 50'
Horizontal 1" = 500'
10 x Vertical Exaggeration
EXPLANATION
LITHOLOGIES
Qal Alluvium
Fine grained (silts & clays)
Coarse grained (gravels & sands)
Tkd Denver
Shale and silty shale
Siltstone & sandy shale
Sandstone
Contact between Qal & Tkd
Contact between sandstone & shale in Tkd—dashed where inferred
SYMBOLS
Bore (dashed where projected > 100 ft. from foreground)
Water level (3/86)
Screened interval
Outline of slurry wall

1 of 2

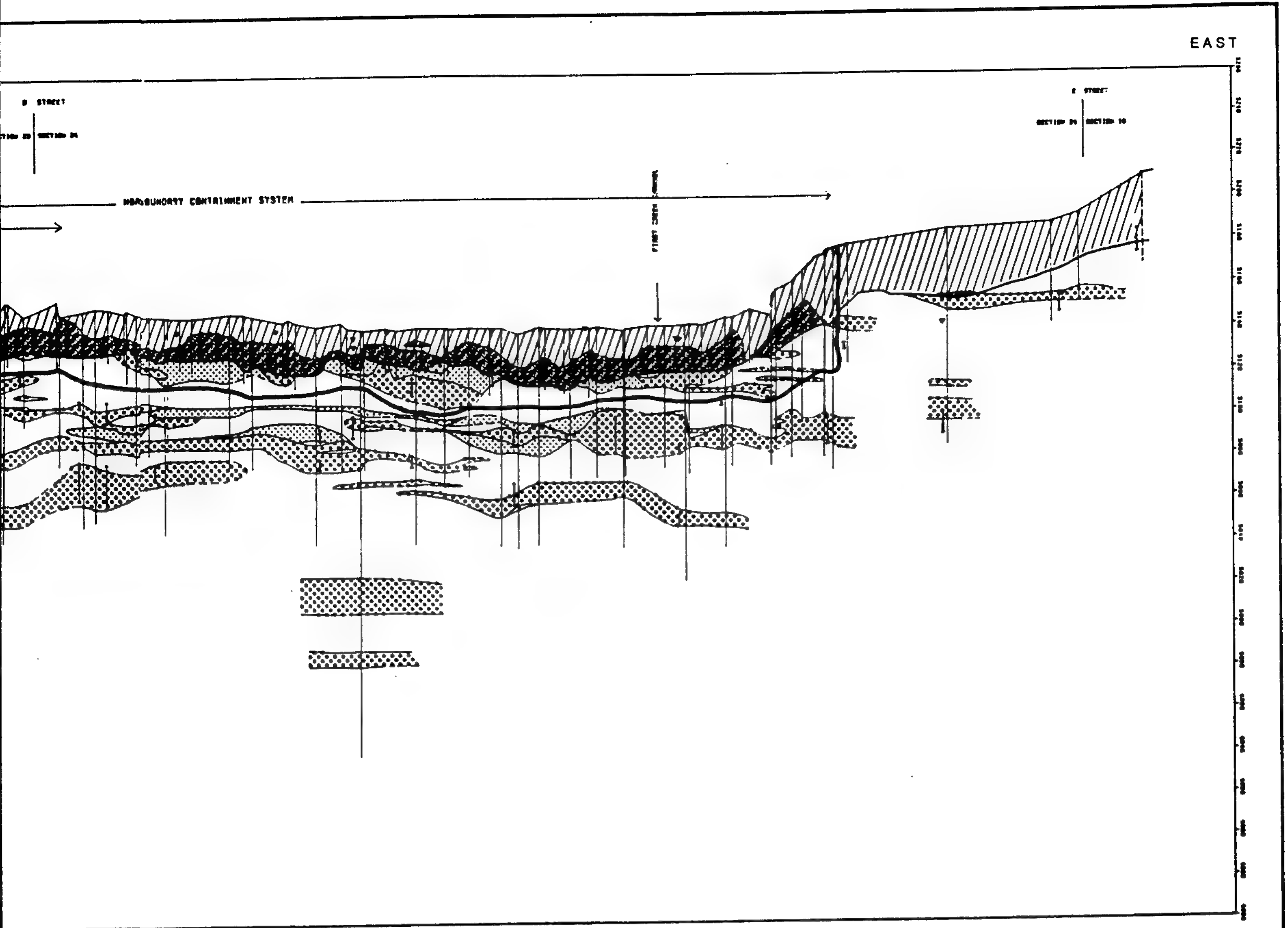


Figure 1.2-2
GEOLOGICAL CROSS SECTION AT THE
NORTH BOUNDARY CONTAINMENT SYSTEM

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U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

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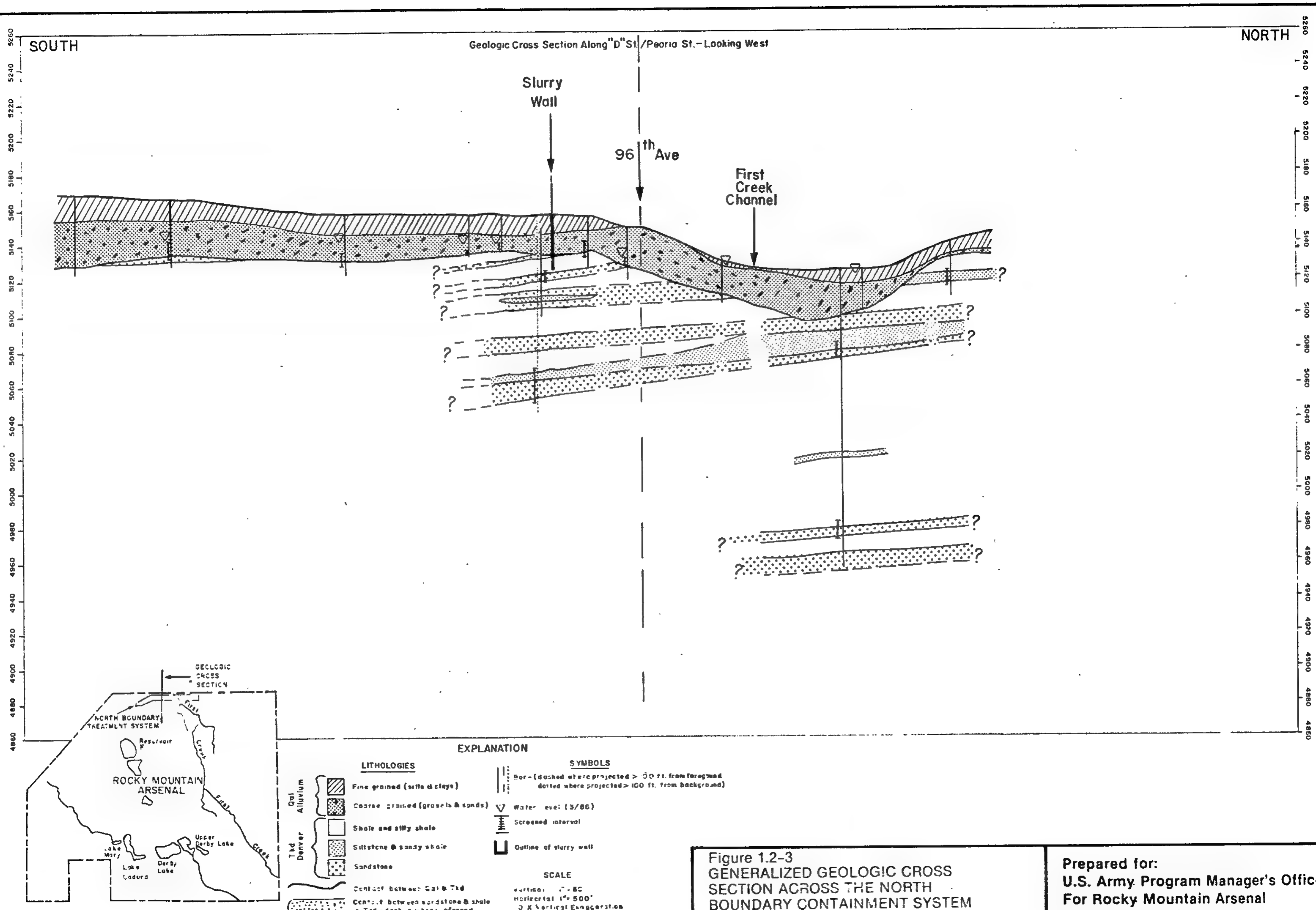

Figure 1.2-3
GENERALIZED GEOLOGIC CROSS SECTION ACROSS THE NORTH BOUNDARY CONTAINMENT SYSTEM
(Looking Due West)

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For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

1.2.2 HYDROLOGY

Near the north boundary of RMA the unconsolidated sediments are saturated to a maximum thickness of 25 ft with an average thickness of 15 ft. About 55 to 60 percent of the saturated unconsolidated sediments are sand and gravel and 40 to 45 percent are silt and clay. Horizontal flow rates through these alluvial sediments near the North Boundary (see cross-section Figures 1.2-2) are estimated at 250 to 325 gallons-per-minute (gpm) toward the north, under an average hydraulic gradient of 0.001 (Figure 1.2-4).

Aquifer tests performed on sediments near NBCS gave the following results:

Sediment Type	Hydraulic Conductivity (gpd/ft^2) Range	Average
Holocene		
Sand and gravel	1×10^3 to 1×10^4	3×10^3
Silt and clay	1×10^2 to 8×10^2	
Denver Formation		
Sands	5 to 40	
Shales and silts	1×10^{-2} to 2×10^{-2}	

In general, the Denver Formation sandstones have a hydraulic conductivity of about three orders of magnitude less than the alluvial sediments. The shale has previously been assumed to have a much lower hydraulic conductivity than both the alluvium and Denver sandstones, but May, et al. (1980) state that field slug tests and laboratory permeability tests have shown in some instances that permeability of fractured clay shale is comparable to that of the Denver sandstones.

The trend of the piezometric surface for the sandstones indicates overall net flow in the Denver aquifers to be to the north and northwest. Detailed knowledge of the hydrogeology and the localized ground water flow components in the Denver Formation, in the vicinity of the NBCS, is limited at present. Ground water modelling as a part of Task 39 (offpost) as well as the

detailed geologic analysis of the Denver Formation in this task, will shed considerable light on the local hydrology and interaction between the alluvial and Denver aquifers.

1.2.3 SYSTEM CONSTRUCTION

The NBCS incorporates 54 dewatering wells upgradient from a soil-bentonite slurry wall to intercept the natural flow of ground water approaching the boundary. Thirty-five dewatering wells are screened in the alluvium and nineteen dewatering wells are screened in several of the Denver sand units. Construction of the system was in two phases in 1978 and 1981. The pilot system was constructed to be 1,500-ft long and had 6 dewatering and 12 recharge wells. The expansions were added as "wings" to the original barrier and extend 3,840 ft due east and 1,400 ft south (70°) west. The total bentonite barrier is 6,740-ft long and approximately 3-ft wide, with a design permeability of 1×10^{-7} cm/sec or less. The barrier depth varies from 20 ft at the pilot system to over 40 ft along the eastern extension where a paleovalley cuts into bedrock. The barrier is anchored in the Denver Formation. The system was designed to remove, treat, and inject, treated ground water flowing through the North Boundary area in both the alluvium and upper Denver sands.

The dewatering wells are divided into three collection manifolds that intercept and dewater separate segments of the aquifer. Figure 1.2-5 shows the manifold alignment. Manifold A is the westward-most section of the system and contains 12 alluvial dewatering wells and 11 Denver sand wells. These are alluvial wells 301 through 306, 330 through 335, and Denver wells 336 through 343. Manifold A primarily intercepts the DIMP plume. Manifold B, which intercepts the DBCP plume, begins east of D Street and includes only 12 alluvial wells. Manifold C includes the easternmost section of the system alignment and is made up of 11 alluvial wells and 8 Denver wells. Manifold C intercepts trace concentrations of DBCP.

Ground water from each manifold is fed to a separate sump prior to entering the carbon adsorption treatment system. The use of separate adsorbers optimizes carbon bed life and removal efficiencies. The treatment system is

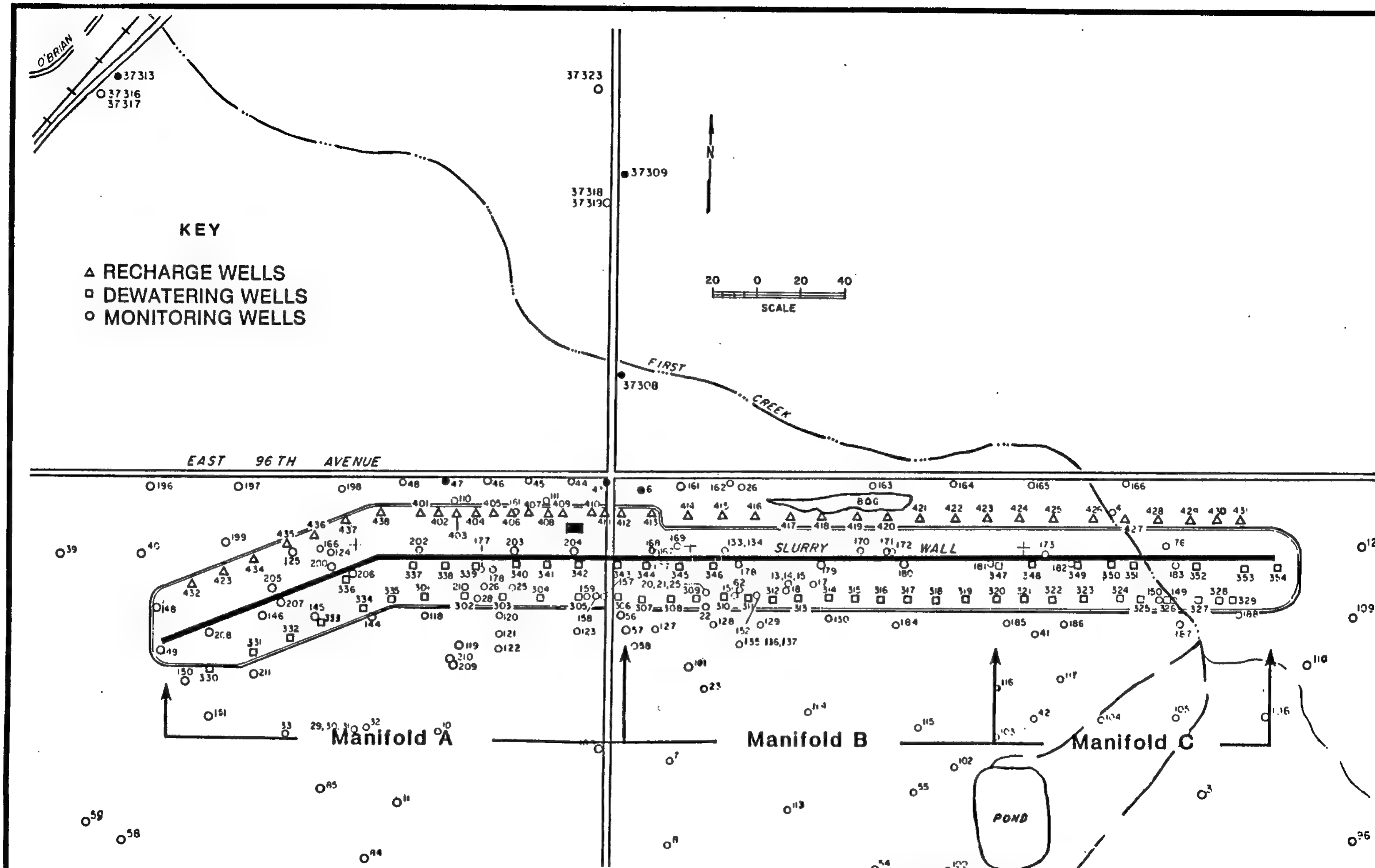

Figure 1.2-5
NORTH BOUNDARY CONTAINMENT SYSTEM

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Aberdeen Proving Ground, Maryland

made up of a cartridge-type prefilter to remove suspended solids from the water, three 30,000-lb upflow pulsed-bed carbon adsorbers, a carbon transfer and storage vessel, and a cartridge-type postfilter (Figure 1.2-6). Treated ground water is discharged to a common sump prior to recharge.

Recharge to the alluvium is accomplished through 38 reinjection wells located downgradient from the slurry wall. The treated water is gravity fed to the 38 wells which are spaced to allow continued diffusion and dispersion in a manner similar to that which occurred prior to system implementation. All recharge is to the alluvium including treated ground water from the Denver sands dewatering wells.

The withdrawal and treatment components of the system have a theoretical capacity of 600 gpm but this is limited in practice to 150 to 350 gpm by weather conditions and mechanical malfunctions. The recharge capacity of the system is lower than the practical withdrawal/treatment component and is limited by periodic plugging of wells and low permeability of sediments along the west end of the system.

1.2.4 SYSTEM OPERATION

Documentation of the operational history of the system is good. The plant operator maintains a log of operations and major events are documented on a weekly basis. The log covers operation, maintenance, and repair of all operating system components. During the 1983-1984 period covered by the Performance Report of Thompson, et al. (1985), several problems were noted which affected overall system performance. These included: mechanical problems rendering some dewatering and recharge wells inoperable (freezing, lightning strikes), difficulty detecting that mechanical failures had taken place which in turn often led to the compounding of a problem, plugging of recharge wells with carbon fines, and failure of the system to handle severe flooding brought on by periodic storm events.

The system was designed to handle the total ground water flow toward the barrier. However, all of the listed problems, acting either individually,

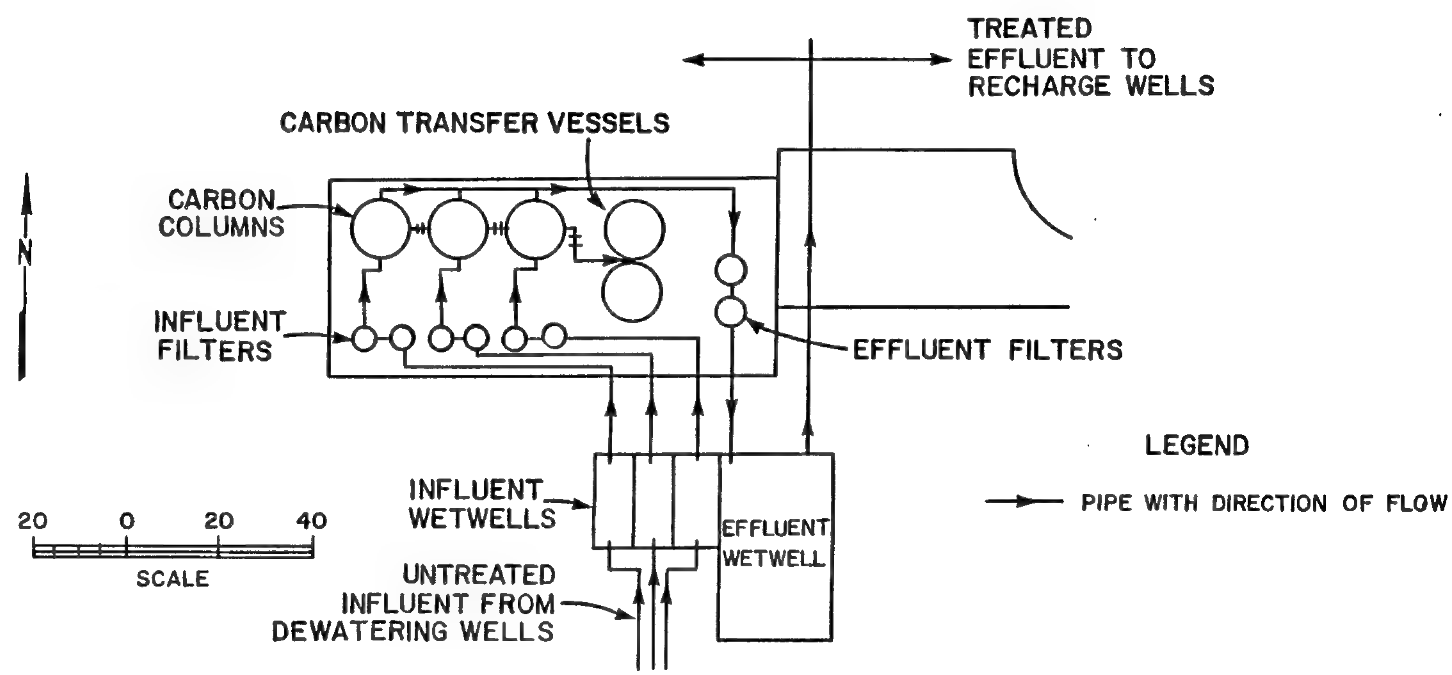


Figure 1.2-6
GROUND WATER TREATMENT FACILITY

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

together, or with other undetected operational problems, have resulted in the system operating at less than design capacity.

The resulting under-capacity of the system has lead to the development of a substantial differential head across the barrier wall. This head is much higher than the original design concept.

The operations log of the treatment systems shows that for the most part, the treatment facility is capable of removing the organic contaminants from the influent to acceptable levels. In addition, the blending of the treated effluent substantially reduces the overall concentrations of the inorganic contaminants, chloride and fluoride.

1.3 SUMMARY OF TECHNICAL APPROACH

The documentation of operational problems with the NBCS in the 1985 Performance Report (Thompson, et al.) and the continued detection of contaminants offpost have dictated that a more detailed performance evaluation be done of the system. Task 36 will undertake that evaluation and fulfill the following objectives:

- Assess the dewatering and recharge components of the system through a review of the operational data, performance testing of the components and evaluation of additional geotechnical data;
- Assess the configuration of the Denver Formation sandstones and the fractured clay shale and evaluate their hydrologic characteristics, especially in the area of the Pilot System, through the acquisition and evaluation of additional geologic and hydrologic data;
- Assess the physical condition of the soil-bentonite barrier wall through in situ and laboratory testing, especially in areas suspected of having problems. The testing will consider physical and chemical degradation of the wall; and
- Develop recommendations for integrated operational modifications and/or design changes that will alleviate the documented problems in the NBCS and achieve positive control of contaminated ground water in both alluvial and Denver aquifers. Operating goals will include recharge capability for 125 percent of dewatering flow

distributed so as to minimize hydrologic impact. They will consider normal well efficiency and historical down-time factors.

To achieve the listed objectives, an integrated geotechnical program will be undertaken to collect the necessary geologic, hydrologic, physical, and chemical data. This will include the installation of additional water level and/or water quality monitoring wells, rock and soil sampling, logging, and barrier sampling. Several in situ tests and laboratory tests are also proposed. Details of these are described in Section 3.0. This program will interface with the geotechnical programs for Tasks 4, 25, 39, and future Task 44 where appropriate to minimize the duplication of effort. The data acquired through the geotechnical program will be integrated with the existing data network and will be evaluated with a historical perspective to fully assess all of the problems noted. The data will be used to produce contamination maps and plots, hydrographs, water level maps, geologic cross sections, and maps to characterize the three dimensional ground water flow and contaminant transport in the vicinity of the NBCS. The data from the operational evaluation and physical testing of the barrier will be used to produce plots to determine operational parameters for the system.

2.0 DATA COMPILATION

Task 36 will be an extension of previous geotechnical work carried out over the past 30 years. This portion of the program will be conducted in two discrete phases. The first phase will consist of a compilation of data and results from past and ongoing programs. This work will involve reviewing all pertinent information on file at the RMA Information Center (RIC) and the Program Managers Office-Rocky Mountain Arsenal (PMO-RMA) as well as interviewing technical experts in the PMO-RMA, U.S. Corps of Engineers (COE), U.S. Environmental Protection Agency (USEPA), and other agencies with a knowledge of the NBCS. This will enable us to evaluate wells that have been sampled in the past, utilize previous aquifer tests, analyze historic onpost contaminant plumes, and to develop a overall geological and hydrological understanding of the NBCS area based on existing data. This review will be fundamental to identifying data gaps and to the final assessment of the design and operation of the NBCS. All data will be evaluated for its applicability to the barrier investigation, the Denver Sands evaluation and the analysis of the dewatering/recharge system.

The second phase of data compilation will consist of compiling new water level and water quality data into a comprehensive data base. This information will be supplemented by additional geologic data, evaluations of dewatering and recharge wells, and barrier investigations. This second phase will supply all the additional data required to perform a reliable assessment of all major NBCS components and to conceptually identify any response actions that may be required for more efficient operation.

3.0 GEOTECHNICAL PROGRAM

The purpose of the geotechnical program will be to acquire the necessary geologic, hydrologic, chemical, and engineering data to adequately address the overall effectiveness of the NBCS. Field activities will include drilling boreholes, collecting barrier and geologic samples, installing ground water monitoring wells, measuring water levels, obtaining ground water quality samples, and conducting aquifer tests. Affiliated laboratory activities will include testing of geologic samples and barrier samples to determine physical properties such as composition, permeability, and grain size.

3.1 SUBSURFACE INVESTIGATION PROGRAM

Ground water levels and ground water quality samples are being taken from a network of existing wells as part of Tasks 4, 25, and future Task 44. Information collected in these field programs will be utilized where appropriate to fulfill the data requirements for this task. In addition, the site selection process for the placement of new monitor wells for this task will be coordinated with the needs of other tasks so that new well installation is optimized. The data collected from these new wells will be compatible with the requirements of all tasks involved because the concurrent geotechnical programs will utilize the same field and management teams, techniques, and procedures.

The construction of existing wells has been evaluated for sampling suitability as part of Tasks 4 and 25. Those rating efforts have been used to select a network of existing wells which are suitable for use in this program. In addition to utilizing the construction information, such as screened interval and construction materials, the wells utilized for the Task 36 evaluation will be evaluated for sampling history and geographic location after completion of the Task 25 First Quarter Sampling Program.

Tables 3.1-1 and 3.1-2 and Figure 3.1-1 show the existing wells selected for Tasks 4 and 25 which can be used for water levels and water quality sampling in this task. A construction and installation evaluation system was

Table 3.1-1. Task 25 Monitoring Network Selected for the North Boundary Containment System (Page 1 of 6)

Well Number	Aquifer*	Classification for Chemical Sampling	Water Level	Chemical Sampling	Sampled Previously
23002	Al	Q	X		
23003	Al	U	X		
23004	Al	Q	X	X	X
23006	Al	U	X		
23007	Al	P	X		
23008	Al	Q	X	X	X
23009	Al	Q	X		x
23010	Al	Q	X	X	X
23011	Al	Q	X	X	X
23012	Al	U	X		
23013	Al	Q	X	X	X
23014	Al	Q	X	X	X
23015	Al	Q	X		X
23016	Al	U	X	X	X
23025	Al	Q	X		
23026	Al	Q	X		
23029	Al	Q	X	X	
23030	Al	U	X		
23033	Al	U	X		
23034	Al	Q	X		
23036	Al	Q	X		
23038	Al	Q	X		
23039	Al	Q	X	X	
23040	Al	Q	X		
23043	Al	U	X	X	X
23044	Al	U	X		
23045	Al	U	X	X	
23046	Al	U	X		
23047	Al	U	X	X	X
23048	Al	Q	X	X	
23050	Al	U	X	X	X
23051	Al	U	X		
23052	Al	Q	X	X	X
23053	Al	Q	X		
23054	D	Q	X		
23055	Al	U	X		
23056	Al	Q	X		
23057	Al	Q	X	X	X
23058	Al	Q	X		
23059	Al	Q	X		
23060	Al	P	X		
23061	Al	Q	X		
23062	Al	U	X		

Table 3.1-1. Task 25 Monitoring Network Selected for the North Boundary Containment System (Continued, Page 2 of 6)

Well Number	Aquifer*	Classification for Chemical Sampling	Water Level	Chemical Sampling	Sampled Previously
23063	Al	Q	X		
23064	Al	Q	X		
23066	Al	Q	X		
23067	Al	Q	X		
23070	Al	Q	X		
23072	Al	U	X		
23079	Al	U	X		X
23084	Al	U	X		
23085	Al	U	X	X	X
23092	Al	U	X		
23094	Al	Q	X		
23096	Al	Q	X		
23097	Al	Q	X	X	X
23099	Al	Q	X		
23101	Al	U	X		
23102	Al	U	X	X	X
23106	Al	U	X	X	X
23107	Al	P	X		
23109	Al	Q	X		
23110	Al	Q	X		
23111	Al	Q	X		
23118	Al	Q	X	X	
23119	Al	Q	X	X	
23120	Al	Q	X	X	X
23121	Al	Q	X		
23122	Al	Q	X		
23123	Al	Q	X	X	X
23124	Al	U	X		
23128	Al	Q	X		
23129	Al	Q	X		
23131	Al	P	X		
23132	Al	Q	X		
23134	Al	U	X		
23135	Al	U	X		
23136	Al	Q	X		
23137	Al	Q	X		
23140	Al	Q	X		
23141	Al	Q	X		
23143	Al	Q	X		
23144	Al	Q	X	X	
23145	Al	Q	X		X
23146	Al	Q	X		

Table 3.1-1. Task 25 Monitoring Network Selected for the North Boundary Containment System (Continued, Page 3 of 6)

Well Number	Aquifer*	Classification for Chemical Sampling	Water Level	Chemical Sampling	Sampled Previously
23148	Al	Q	X		
23149	Al	Q	X		
23150	Al	Q	X	X	
23151	Al	Q	X	X	
23157	Al	Q	X		
23160	Al	Q	X	X	X
23161	D	A	X	X	X
23162	D	A	X		
23173	D	A	X	X	
23174	D	A	X	X	X
23176	Al	P	X		
23178	Al	Q	X		
23181	D	A	X	X	
23184	D	A	X		X
23189	Al	A	X	X	
23193	D	A	X		
23196	Al	P	X	X	X
23197	Al	P	X	X	
23198	Al	P	X	X	X
23199	Al	Q	X		X
23200	D	P	X	X	X
23201	D	P	X	X	
23202	Al	Q	X	X	X
23203	Al	P	X	X	X
23204	Al	P	X	X	X
23205	Al	P	X	X	
23207	Al	P	X		
23208	Al	U	X	X	
23209	D	Q	X	X	X
23210	D	Q	X	X	
23211	Al	P	X	X	
24001	Al	P	X		
24002	Al	P	X		
24003	Al	Q	X	X	
24004	Al	Q	X		X
24007	Al	Q	X		X
24008	Al	Q	X	X	X
24009	Al	Q	X		
24010	Al	Q	X	X	X
24013	Al	Q	X	X	X
24014	Al	Q	X		
24015	Al	Q	X		
24016	Al	Q	X		

Table 3.1-1. Task 25 Monitoring Network Selected for the North Boundary Containment System (Continued, Page 4 of 6)

Well Number	Aquifer*	Classification for Chemical Sampling	Water Level	Chemical Sampling	Sampled Previously
24017	Al	Q	X	X	X
24018	Al	Q	X		
24019	Al	Q	X		
24020	Al	Q	X		
24021	Al	Q	X		
24022	Al	Q	X		
24023	Al	Q	X	X	X
24024	Al	Q	X	X	X
24025	Al	Q	X		
24027	Al	Q	X	X	X
24043	Al	Q	X		
24045	Al	Q	X		
24048	Al	Q	X		
24049	Al	Q	X	X	X
24050	Al	Q	X		
24051	Al	Q	X		
24052	Al	Q	X		
24053	Al	Q	X		
24054	Al	Q	X		
24055	Al	Q	X		
24056	Al	Q	X		
24057	Al	Q	X		
24062	Al	Q	X		
24063	Al	Q	X	X	X
24064	Al	Q	X		
24065	Al	U	X		
24080	Al	Q	X		
24081	Al	Q	X	X	X
24083	Al	Q	X		
24085	Al	Q	X		
24086	D	Q	X	X	
24087	Al	Q	X		
24088	Al	Q	X	X	
24089	Al	Q	X		
24090	Al	Q	X		
24091	Al	U	X		
24092	Al	Q	X		
24093	Al	Q	X		
24094	Al	Q	X	X	
24095	Al	Q	X		
24096	Al	Q	X	X	
24097	Al	Q	X		
24098	Al	Q	X		
24099	Al	Q	X		X

Table 3.1-1. Task 25 Monitoring Network Selected for the North Boundary Containment System (Continued, Page 5 of 6)

Well Number	Aquifer*	Classification for Chemical Sampling	Water Level	Chemical Sampling	Sampled Previously
24100	Al	Q	X		
24101	Al	Q	X		X
24102	Al	Q	X		
24103	Al	Q	X		
24104	Al	Q	X		
24105	Al	Q	X		
24106	Al	Q	X	X	
24107	Al	Q	X	X	
24108	Al	Q	X	X	
24109	D	Q	X	X	
24110	Al	Q	X	X	
24111	Al	Q	X	X	X
24112	Al	Q	X		
24113	Al	Q	X	X	X
24114	Al	Q	X		
24115	Al	Q	X	X	X
24117	Al	Q	X		
24120	D	Q	X	X	
24121	Al	Q	X		
24122	Al	Q	X		
24123	Al	Q	X		
24124	D	Q	X	X	X
24125	D	Q	X		
24126	D	Q	X		
24127	D	Q	X	X	X
24128	D	Q	X	X	
24129	D	Q	X		
24130	D	Q	X		X
24135	D	Q	X		X
24137	D	P	X		
24148	Al	Q	X		
24149	Al	P	X		
24151	Al	Q	X		
24154	Al	Q	X		
24156	D	P	X		
24161	Al	P	X	X	
24162	Al	P	X	X	X
24163	Al	P	X	X	X
24164	Al	P	X	X	
24166	Al	P	X	X	
24167	D	Q	X	X	X
24168	D	Q	X	X	X
24169	Al	Q	X		

Table 3.1-1. Task 25 Monitoring Network Selected for the North Boundary Containment System (Continued, Page 6 of 6)

Well Number	Aquifer*	Classification for Chemical Sampling	Water Level	Chemical Sampling	Sampled Previously
24170	Al	P	X	X	
24171	D	Q	X	X	X
24172	D	P	X	X	
24174	D	P	X	X	
24175	D	P	X	X	
24176	Al	P	X	X	
24177	Al	Q	X	X	
24179	Al	P	X	X	
24180	Al	Q	X	X	X
24181	Al	Q	X	X	
24182	Al	Q	X	X	
24183	Al	P	X	X	
24184	Al	P	X	X	X
24186	Al	Q	X	X	X
24187	Al	Q	X	X	
24188	Al	P	X	X	
37306	Al	A	X	X	
37316	D	A	X	X	X
37317	Al	A	X	X	X
37318	Al	A	X	X	X
37319	D	A	X	X	
37321	D	A	X	X	X
37322	D	A	X	X	X
37323	Al	A	X	X	X
37327	Al	A	X	X	X

* = Aquifer in which well was screened.
Al = Alluvial
D = Denver

Classification for Chemical Sampling

Q = Questionable
P = Possible
A = Acceptable
U = Unacceptable

Source: ESE, 1986.

Table 3.1-2. Task 4 Monitoring Network for the North Boundary Containment System

Well Number	Aquifer*	Classification for Chemical Sampling	Water Level	Chemical Sampling	Sampled Previously
23049	Al	Q	X		
23095	Al	U	X		
23108	Al	U	X		
23125	Al	Q		X	
23142	Al	Q	X		
23166	Al	P	X		X
23177	D	A	X	X	X
23179	Al	A	X		
23180	D	A	X		
23182	Al	A	X		
23183	D	A	X		
23185	Al	A	X		
23186	D	A	X		
23187	D	A	X		
23188	Al	A	X		
23190	D	A	X		
23191	Al	A	X		
23192	D	A	X		
24196	D	P	X		
24150	D	P	X		
24158	D	P	X		
24159	D	A	X		
24178	A	P	X	X	
24185	A	P	X		

* = Aquifer in which well was screened
Al = Alluvial
D = Denver

Classification for Chemical Sampling

Q = Questionable
P = Possible
A = Acceptable
U = Unacceptable

Source: ESE, 1986.

established in Task 4 and utilized in the classification of wells for Task 25.

The Task 25 wells were classified as Acceptable, Possibly Acceptable, or Questionable, based on construction criteria; however, some wells classified as Unacceptable were included (see Tables 3.1-1 through 3.1-2) in the monitoring network. These wells were chosen because they had been sampled in the past and a continuity of data was deemed important.

The Task 36 well network will supplement the existing network cited above and the proposed sites which will be installed under Tasks 25 and 39. It is estimated that approximately 16 additional sites and a total of 30 water quality wells will be installed based on a preliminary review of existing data. The majority of these wells will be located downgradient of the barrier. This system will be augmented by a system of approximately 10 to 20 water level measuring wells which will be placed closely around the soil-bentonite barrier.

A preliminary round of water quality and water level samples will be taken from a number of the first wells installed to help pinpoint the locations of additional wells and direct the barrier sampling program. After this initial round, water quality and water level sampling will be incorporated into a comprehensive program that will include new and existing wells from Task 4, 25, and 39.

The Task 36 network of boreholes and wells will be selected to provide additional water level and water quality data, define geologic and hydrologic conditions close to an within the barrier, and examine possible routes of contaminant transport near the NBCS. This data will be gathered in sufficient detail to adequately evaluate the dewatering/ recharge system, the soil-bentonite barrier, and Denver Sands units.

3.1.1 RATIONALE FOR INVESTIGATION

New monitoring wells and barrier investigations have been proposed to supplement data from the existing well network and to assess the integrity

of the soil-bentonite barrier. The specific location and rationale for sites will be outlined in Letter Technical Plans that will be incorporated in Section 10.0. The investigations are broken down into sites upgradient of the system, sites downgradient of the system, and actual barrier investigations. This breakdown is convenient because the rational for each of these subcategories are similar. The sites chosen for each group are based on supplementing data from Task 4 and 25 and the evaluation of all data accumulated under Phase I of the Data Compilation Program described in Section 2.0. The program is planned to provide the additional geologic, hydrologic, and water quality data needed to adequately evaluate the different components of the NBCS.

3.1.1.1 Barrier Investigation

Actual investigation of the soil-bentonite barrier will be directed by historic and new data on contaminant distributions and water levels around the NBCS. The proposed sampling plan will follow guidelines set forth in Section 3.8.2 and is intended to assess the overall condition of the barrier, particularly in the vicinity of the pilot barrier. It is estimated that approximately five to ten sample locations will be required to provide a statistically representative view of the barrier's condition. The testing program for barrier samples is outlined briefly in Section 3.9.1.

The barrier assessment also includes the installation of water level monitoring wells immediately around the barrier (Section 3.3) and the sampling of fractured bedrock units beneath the barrier (Section 3.8.1). This data will supplement the actual barrier investigation to provide a comprehensive assessment of the barrier's effectiveness in retarding ground water flow.

3.1.1.2 Sites Downgradient of Barrier

Several new downgradient monitor wells have been proposed to fill gaps in the existing downgradient well network. At this time, 11 sites have been proposed. After Phase I of the Data Compilation portion of the study is complete and timely comments have been reviewed, additional sites will be proposed and preliminary sites may be shifted to ensure that data is

obtained in areas where it is most needed. The specific location and types of wells proposed for each site will be documented in Letter Technical Plans that will be included in Section 10.0 of the Technical Plan.

Downgradient sites will consist of both onpost and offpost sites. For offpost sites, consideration has been given to ease of access and land-use patterns. The monitoring needs for Tasks 25, 39, and future Task 44 are also incorporated into the siting selection. Monitor wells to be installed by all three tasks have been assembled into a consolidated drilling program to maximize field efficiency and obtain more favorable rates from drillers and other subcontractors.

The Task 36 downgradient wells will be sited to meet the following objectives:

- o Provide water level and water quality data in sufficient detail to evaluate system performance;
- o Define in detail the geologic and hydrologic conditions downgradient of the NBCS, and how this information correlates with data at and upgradient of the barrier; and
- o To help determine possible routes of contaminant transport under, around, or through the barrier wall.

Downgradient sites are summarized in Table 3.1-3 and shown in Figure 3.1-2. Proposed site numbers were assigned to sites sequentially and do not reflect any inherent priority. Additional site rationale is outlined in ESE's Letter Technical Plan of November 26, 1986 (Section 10.0). At this time 11 sites have been chosen which are concentrated in the offpost area or onpost immediately downgradient from the system. Six offpost sites, (E-34, E-39 through E-42, E-63) have been chosen because of the long expected lead time for permit acquisition. The placement of three (E-34, E-39, E-63) of these six sites are nearly certain. E-39 and E-63 are cluster well sites with one alluvial and two new Denver wells in vital locations (lacking geologic, hydrologic, and water quality data), while E-34 is a cluster well site of two Denver wells at existing alluvial well site 37338.

Table 3.1-3. List of Proposed Well and Borehole Sites

Site	Location	Owner
E-32	NE/4, NE4 Section 23 (23043)	RMA
E-33	NW/4, NW/4 Section 24 (24026 or 24163)	RMA
E-34	SE/4, SW/4 Section 13 (37338)	Adams County
E-35	NE/4, NE/4 Section 24 (bore only)	RMA
E-39	SE/4, SW/4 Section 14	Private
E-40	SW/4, SE/4 Section 14	Private
E-41	SE/4, SE/4 Section 14	Private
E-42	SE/4, SE/4 Section 14	Private
E-63	SW/4, SW/4 Section 13	Private
E-66	NW/4, NE/4 Section 23	RMA
E-67	NE/4, NE/4 Section 23	RMA

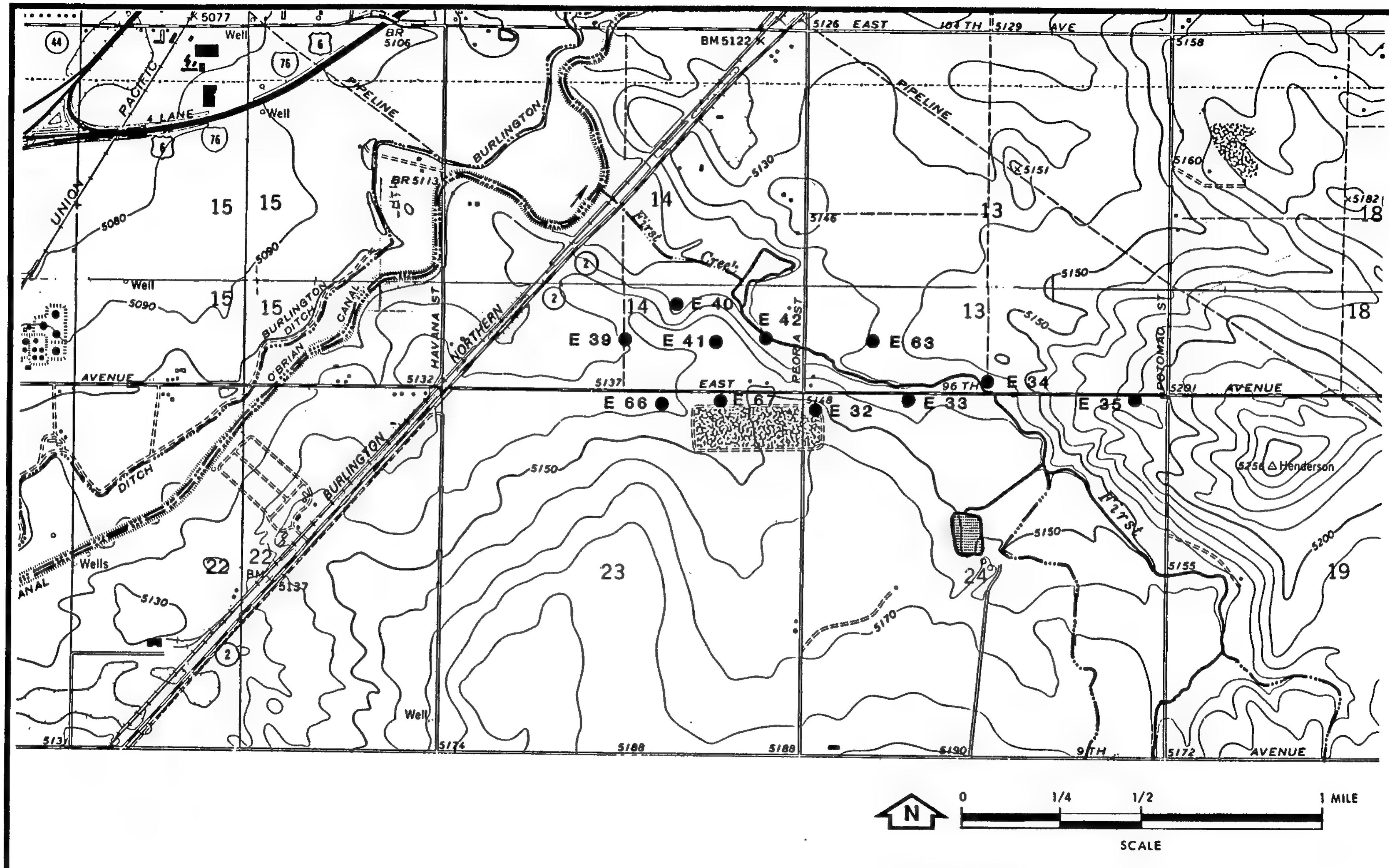


Figure 3.1-2
PROPOSED SITES FOR NEW MONITOR WELLS
AND BOREHOLES FOR TASK 36

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

The remaining three offpost sites (E-40, E-41, E-42) are more flexible sites. It is probable that not all three sites will need to be completed to provide the data required. Final selection or elimination of sites will be determined by the results from the Task 25 First Quarter Sampling Program and Phase I of the Data Compilation portion of this study.

Five onpost sites have been selected to date. E-32 and E-33 are each two Denver well clusters at existing alluvial well sites 23043 and 24026 (or 24163), respectively. Both of these sites fill gaps in geologic, hydrologic, and water quality data networks. E-35 is the site of a borehole to be drilled into bedrock and abandoned. E-67 and E-66 are sites for Denver well clusters at existing alluvial wells 23047 and 23197, respectively, where information on the Denver aquifer is sparse. It is in an area with little geologic data, but where the hydrology and water quality appear to be relatively well understood.

The specific location of the remainder of the onpost downgradient sites will be chosen based on a combination of the following:

- The detailed geologic study to be initiated under Phase I of Data Compilation (Section 2.0);
- The results of the First Quarter Sampling Program from Task 25 (field work is already complete); and
- Preliminary assessment of the historical water level and water quality data presented in the 1984 Performance Report on the NBCS; and
- Consideration of timely comments from Memorandum of Agreement (MOA) parties.

The delay in finalizing the remaining sites is necessitated by the desire to incorporate as much detailed data as possible to meet the exacting location needs of this task. All sites that deviate from this preliminary siting will be addressed in Letter Technical Plans and incorporated into Section 10.0.

All preliminary sites downgradient are described in more detail below:

Site E-32 is a site for the installation of two Denver wells at the location of alluvial well 23043 near the intersection of "D" Street and 96th Avenue. The site is on RMA and is about 50 ft west of the east line and 50 ft south of the north line in the NE/4, NE/4 of Section 23. This site is needed to characterize the geology, hydrology, and contaminant plumes in the Denver aquifer downgradient from the NBCS.

Site E-33 is located just south of 96th Avenue in the NW/4, NW/4 of Section 24 at the site of existing alluvial well 24026 on RMA. This location is about 800 ft east of the west line and 50 ft south of the north line of Section 24. Two Denver wells are proposed to characterize the geology, hydrology, and chemistry in the Denver sandstones north of the NBCS. An alternative site for Site 33 could be 700 ft further east at existing well 24163 or at a more appropriate site between 24026 and 24163 as determined from the detailed geology to be done in the Preliminary Assessment.

Site E-34 is offpost at existing alluvial well 37338 on the north side of 96th Avenue in the SE/4, SW/4 of Section 13. The site is about 2,500 ft east of the west line and 20 ft north of the south line and is on Adams County Highway Department right-of-way. Two wells will be installed to identify the geology and hydrology of the sandstones in the Denver Formation and verify that there is no contamination in this part of the aquifer.

Site E-35 is on RMA approximately 4,800 ft east of the west line and 50 ft south of the north line in the NE/4, NE/4 of Section 24. This is to site a proposed borehole to characterize the Denver Formation geology. The borehole will be abandoned per USATHAMA specification.

Site E-39 is an offpost site located on property denoted by tax record 1721-14-0-05-005 in the SE/4, SW/4 of Section 14 owned by:

City of Commerce City
% Gregg Clements
4407 E. 60th Avenue
Commerce City, Colorado 80022
(303) 289-3701

The area is currently being dryland wheat farmed by Hickey Farm.

% Charles Hickey
3240 Jay Street
Wheatridge, Colorado 80033
(303 233-9003

A 50-ft easement and corridor of access has been requested for the eastern property line of Block 5 of the Adco Industrial Park Subdivision in Section 14 which runs from the center point of Section 14 due south to the midpoint of the south section line of Section 14 (96th Avenue). This is needed to drill a boring and install a permanent cluster of three monitor wells at or near the tentative site which is about 2,600 ft east of the west line and 800 ft north of the south line of Section 14. This site is necessary to characterize the geology, hydrology, and possible contamination of the alluvium and Denver sandstones downgradient of the NBCS.

Site E-40 is offpost located on private property denoted by tax record number 1721-14-0-04-020 in the SW/4, SE/4 of Section 14, approximately 2,000 ft west of the east line and 1,300 ft north of the south line. This property is owned by:

Michael Bruce Collins
11515 East 96th Avenue
Commerce City, Colorado 80022
(303) 288-5969

Access to this property has been requested to install two Denver aquifer monitoring wells adjacent to an existing alluvial well (37305) after an initial boring is completed at the site. An easement of 20 ft along the eastern edge of the property or a satisfactory route chosen by the land owner has been requested. Future access to sample this well cluster will be needed on a periodic basis. This site is necessary to characterize the geology, hydrology, and possible contamination of the alluvium and Denver sandstones downgradient of the NBCS.

Site E-41 is offpost located on private property denoted by tax record number 1721-14-0-04-019 which lies in the SE/4, SE/4 of Section 14 approximately 1,300 ft west of the east line and 600 ft north of the south line and is owned by:

Dorothy Lambert
11921 East 96th Avenue
Commerce City, Colorado 80022
(303) 287-2733

The access to this site is needed to drill a boring and install two Denver aquifer monitoring wells adjacent to an existing alluvial monitoring well (37304). The total permanent area of disturbance would be a 20 ft by 20 ft area adjacent to the fence. Future access to the cluster of wells would be needed for periodic ground water sampling. This land is currently up for sale by the owner. The boring and the installation of wells is required to assess the geology, hydrology, and possible contamination of Denver sandstones downgradient of the NBCS.

Site E-42 is offpost on private property denoted by tax record number 1721-14-0-04-015 in the SE/4, SE/4 of Section 14, tentatively sited approximately 400 ft west of the east line and 660 ft north of the south line. The property is owned by:

Dorothy Lambert
11921 East 96th Avenue
Commerce City, Colorado 80022
(303) 287-2733

A 50-ft easement and corridor of access along the northern boundary of the property or any other suitable route of access as directed by the property owner is requested to gain access to the site to drill a test boring and install a cluster of three monitor wells. Total permanent disturbance will be an area around the well cluster of 20 ft by 20 ft. Future access on a periodic basis to sample the wells will be needed. Data from these installations will be used to evaluate the geology, hydrology, and water quality of the alluvium and Denver sandstones downgradient of the NBCS.

Site E-63 is an offpost site located on private property denoted by tax record 1721-00-0-00-030 in the SW/4 of Section 13 owned by:

Adams County Joint Venture
% Butler and Pierce
720 Kipling Street, Suite 201
Lakewood, Colorado 80215
(303) 232-3888

A 50-ft easement and corridor of access has been requested as part of the overall drilling program along the northern, eastern, and southwestern property lines of the property to drill several borings, and install monitoring wells. There will be three wells at Site E-63. Other sites on this property are part of Task 39. We will be requesting continued access along the north and southwest corridors for periodic sampling. The tentative location for this site is about 1,000 ft east of the west line and 1,000 ft north of the south line of Section 13. This site will be used to obtain geologic, hydrologic, and water quality data in the alluvium and Denver sandstones downgradient of the NBCS.

Tentative sites immediately north and northwest of the pilot portion of the system are listed below:

Site E-66 is tentatively proposed in the vicinity of alluvial well 23197 about 50 ft south of the north line (96th Avenue) and 2,200 ft west of the east line ("D" Street) in Section 23. Two Denver wells are proposed here to gather geologic, hydrologic, and chemical data.

Site E-67 is tentatively proposed near alluvial wells 23047 and 23048 about 50 ft south of the north line (96th Avenue) and 1,000 ft west of the east line ("D" Street) of Section 23. Two Denver wells would be completed there to collect geologic, hydrologic, and chemical data.

Additional sites to be considered would be northwest of the west end of the treatment system as well as several possible sites to fill in areas of data gaps between the NBCS and 96th Avenue where a high degree of detailed data

might be needed. It has been found that some monitor wells in the Denver Formation have been destroyed by maintenance operations (23172 and 23173). Several of these may have been to be replaced as part of this program.

3.1.1.3 Sites Upgradient of Barrier

At present, no specific sites for ground water quality monitoring wells upgradient of the barrier have been chosen. However, it is anticipated that approximately five will be needed and the specific location and type of wells will be outlined in a Letter Technical Plan. As with the downgradient wells, the upgradient wells will be chosen to supplement existing data from Tasks 4 and 25. In particular, siting will utilize the First Quarter Sampling Data from Task 25 (RIC#87014R24) and the data base established in Phase I of the Data Compilation portion of this study. Of particular interest upgradient is the extent and configuration of Denver Sand Units that have been defined at the North Boundary. Piezometric and water quality data from the sites will supplement existing data and permit a more precise evaluation of the extent to which these units may be acting as contaminant transport mediums. Data from these wells will also help determine whether potential point(s) of entry for contamination into Denver Sand Units are substantially upgradient or closer to the soil-bentonite barrier.

3.1.2 PERMITS FOR OFFPOST SITES AND UTILITY COORDINATION

Based on Section 121(e) of the Superfund Amendments and Reauthorization Act of 1986 (SARA), it is the Army's opinion that it is not legally required to obtain state or local drilling permits for new monitoring wells located within the area being evaluated as part of the Army's offpost Remedial Investigation/Feasibility Study (RI/FS). Although new wells constructed offpost as part of Task 36 would be within this area, the Army has decided to continue to obtain drilling permits for such wells as it has done in the past. The Army does not believe that obtaining such permits will be overly burdensome nor delay implementation of Task 36. This practice also assures that the offpost drilling program will remain in substantive compliance with applicable state laws and regulations.

ESE will be responsible for securing such permits on behalf of the Army and for responding to reasonable and timely requests for samples, well logs, and other documentation by government agencies. The Corps of Engineers will be responsible for obtaining right-of-way permits from the Colorado State Engineers Office (CSEO) or other agencies as appropriate. ESE will coordinate the permit activities for this task and other offpost tasks to avoid duplication of effort. ESE will also establish and maintain contact with all utility companies which may have service lines adjacent to the proposed drill sites.

3.2 BOREHOLE DRILLING AND MONITOR WELL INSTALLATION PROGRAM

Boreholes and/or monitor wells will be drilled using auger or rotary techniques according to conditions encountered at the site. Techniques and procedures associated with the drilling program including downhole geophysical surveys will be consistent with those outlined in Section 3.0 of the Task 1 Technical Plan (ESE, 1985, RIC#85127R07) and USATHAMA (1983) Geotechnical Requirements.

3.2.1 INITIATION OF FIELD PROGRAM

Drilling equipment including drill rods, samplers, tools, and water tanks will be steam cleaned prior to arrival at RMA and washed with approved water before arrival at each boring or well site. Water to be used in drilling, grouting, or decontamination will be obtained at a source approved by the PMO-RMA. Only USATHAMA approved lubricants such as petroleum jelly will be used on the threads of downhole drilling equipment. Air usage will be fully documented with equipment descriptions, and oil filter specifications. Only USATHAMA approved air systems will be used.

3.2.2 SAMPLING

Continuous alluvial soil samples will be collected using rotary or hollow-stem auger sampling techniques. The continuous soil samples will be collected in polybutyrate tubes and transferred to a central logging facility. The soil samples will be logged and then stored in the polybutyate tubes or one-pint wide-mouth jars.

Rotary core drilling methods will be used to collect 2 1/2-inch (in) diameter rock cores. Hollow-stem augers or conductor casing will be advanced into bedrock, sealed with bentonite, and then rinsed with approved water to minimize alluvial contamination. The 2 1/2-in rock core will be taken from a depth at least 5 ft below the water bearing unit which is to be screened. The rock core will be logged in detail, photographed, wrapped in plastic, and then stored in cardboard coreboxes.

3.2.3 WELL DRILLING AND INSTALLATION TECHNIQUES

Installation of monitor wells will begin within 12 consecutive hours of borehole completion for uncased or partially cased holes and within 60 consecutive hours in fully cased holes. Once installation has begun, no break in the installation process will be made until the well has been grouted and the protective casing installed. All materials used in well construction will be approved by USATHAMA and PMO-RMA prior to use.

Alluvial Wells--Alluvial wells will be drilled with 8 1/4-inch inside diameter (ID) hollow-stem augers following soil sample collection. The hollow-stem augers will be advanced into bedrock 1 to 2 ft. In general, wells will be screened from the bedrock contact to approximately 5 ft above the water table surface. Wells will be completed inside hollow-stem augers as shown in Figure 3.2-1. The details of the materials and methods to be used in well construction are described in Sections 3.2.4 through 3.2.8.

Bedrock Wells--In general, bedrock wells will be drilled using direct rotary methods. In instances when sloughing of alluvial material is a problem and precautions to prevent cross-contamination are not necessary (Figure 3.2-2a through Figure 3.2-2c), the alluvium can be drilled with hollow-stem augers. In instances where cross-contamination is possible the borehole will be reamed and conductor casing will be telescoped and grouted in place using Halliburton techniques. The specific type of installation will depend on the hydrogeology at the site and the aquifer to be monitored as shown in Figures 3.2-2d through 3.2.2g. Figure 3.2-3 is a schematic drawing of a typical cluster well installation. The well head completion will be the same as those specified for alluvial monitor wells (Figure 3.2-1). Pilot

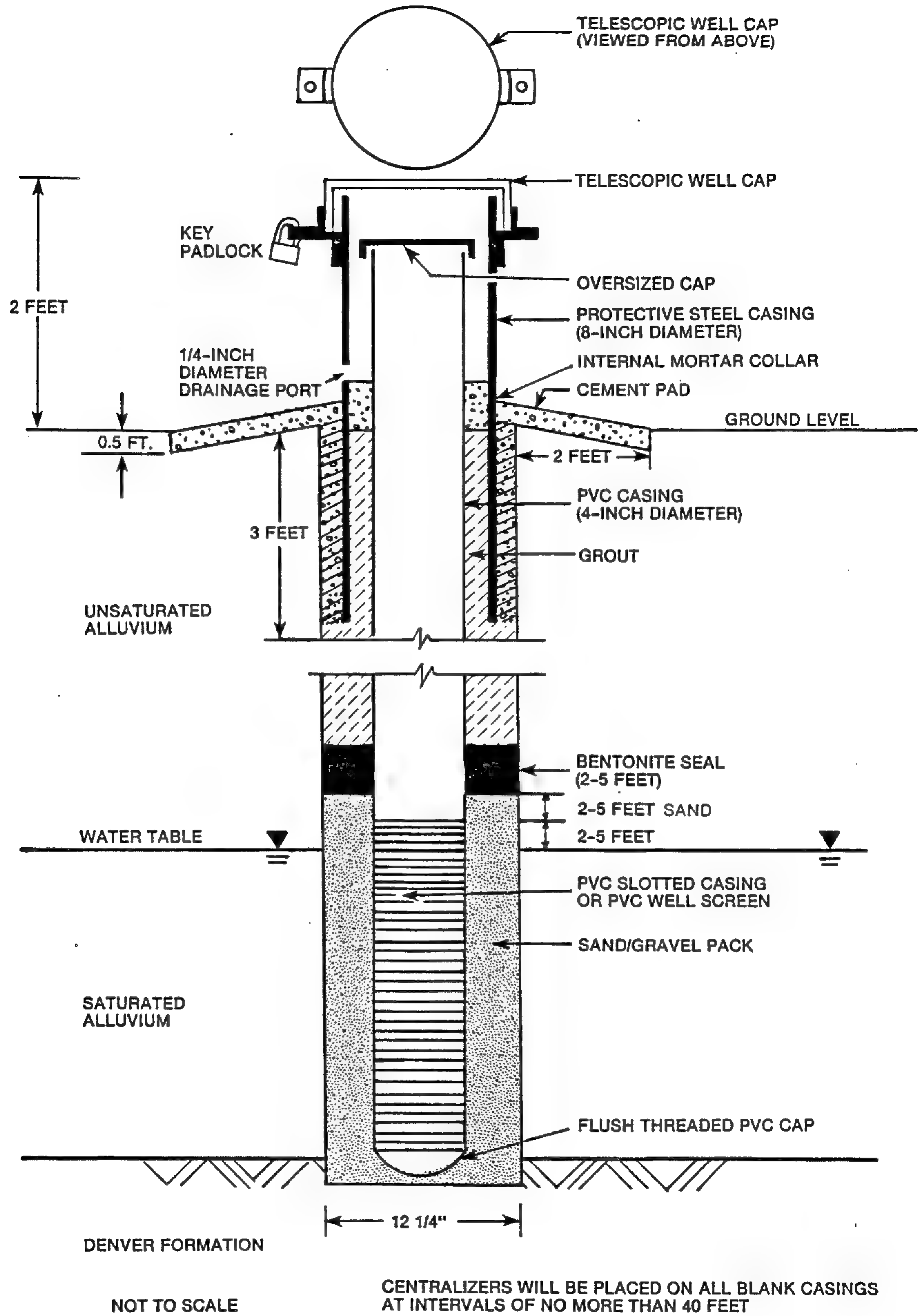
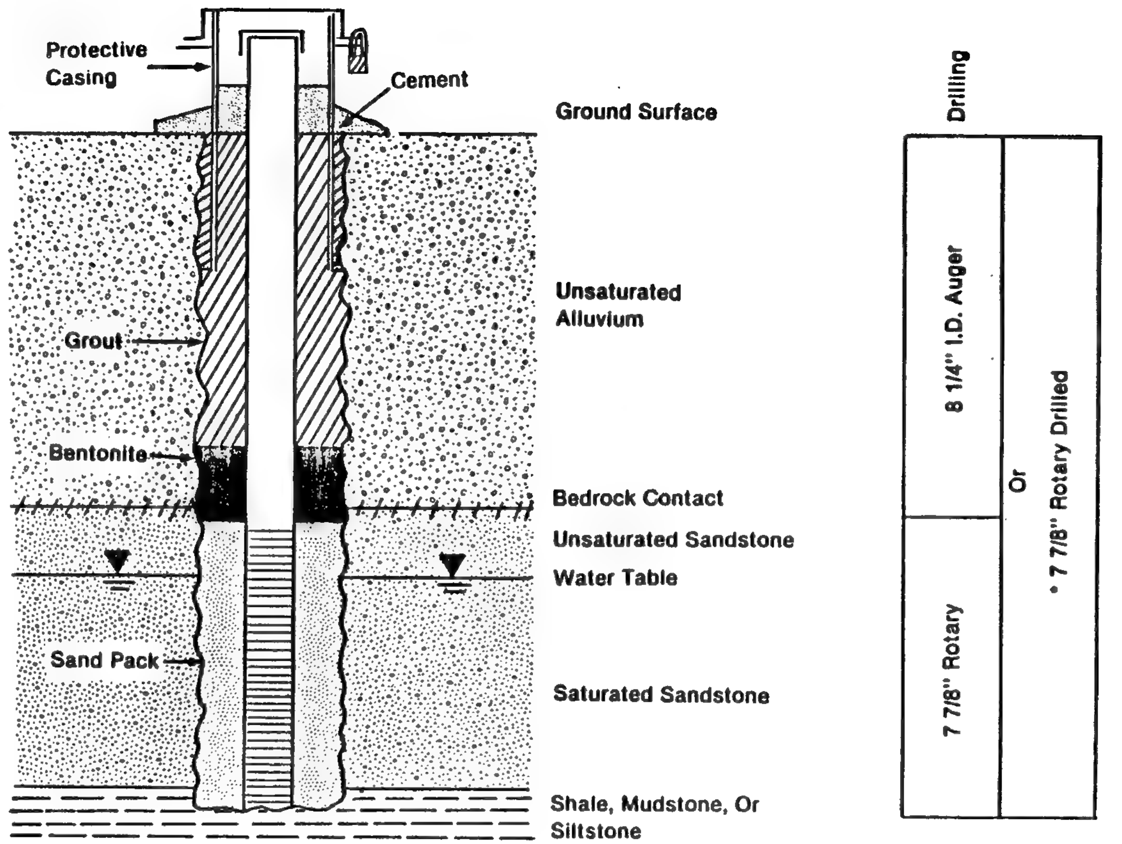


Figure 3.2-1
GENERALIZED AQUIFER MONITOR
WELL CONSTRUCTION

SOURCE: ESE, 1987

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland



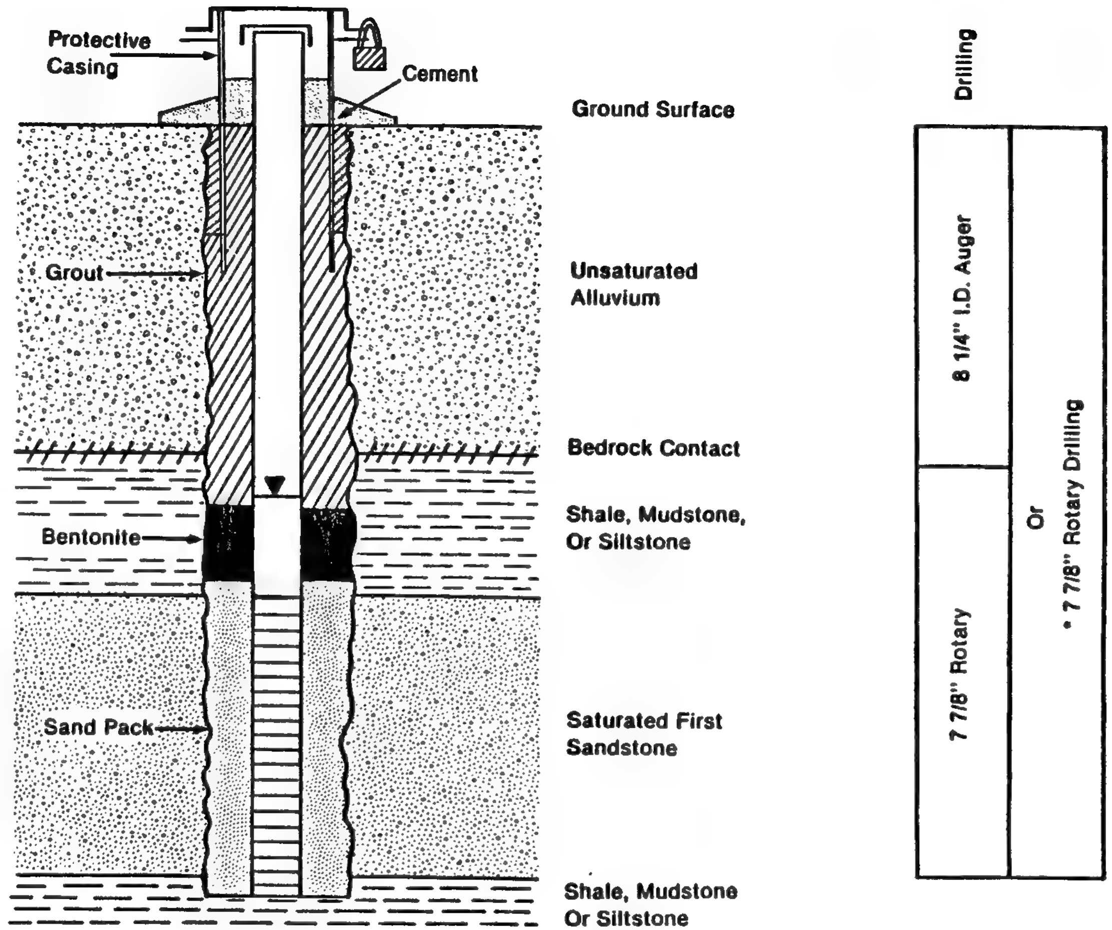
• Field Determination After Drilling Alluvium

CENTRALIZERS WILL BE PLACED ON ALL BLANK CASINGS AT INTERVALS OF NO MORE THAN 40 FEET

Figure 3.2-2a
GENERALIZED BEDROCK AQUIFER MONITOR WELL CONSTRUCTION (DENVER FM. WELL COMPLETED IN FIRST SANDSTONE, ALLUVIUM UNSATURATED, SANDSTONE AT THE ALLUVIAL-BEDROCK CONTACT, SANDSTONE PARTIALLY SATURATED)

SOURCE: ESE,1986

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland



* Field Determined After Drilling Alluvium

CENTRALIZERS WILL BE PLACED ON ALL BLANK CASINGS AT INTERVALS OF NO MORE THAN 40 FEET

Figure 3.2-2b
GENERALIZED BEDROCK AQUIFER MONITOR WELL CONSTRUCTION (DENVER FM. WELL COMPLETED IN THE FIRST SANDSTONE, ALLUVIUM UNSATURATED, SHALE AT THE ALLUVIAL-BEDROCK CONTACT)

SOURCE: ESE, 1986

Prepared for:
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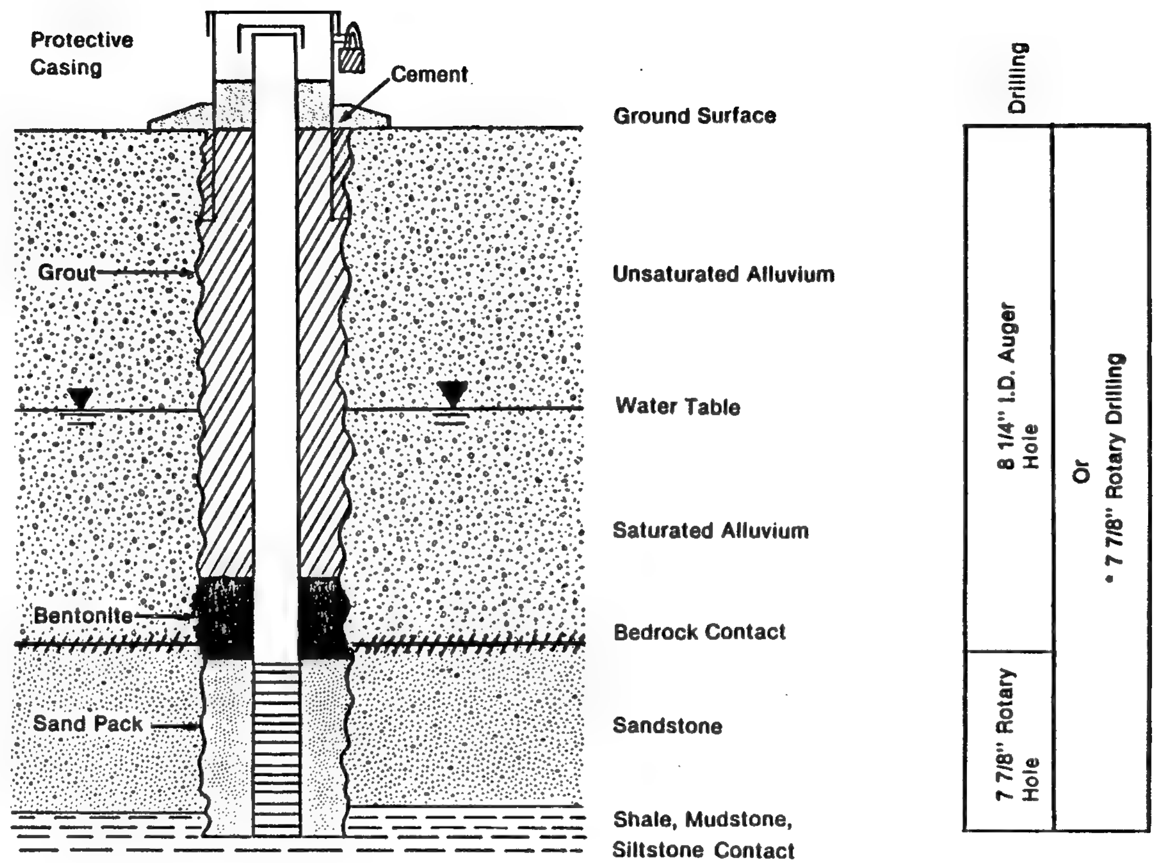
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland



* Field Determination After Drilling Alluvium

CENTRALIZERS WILL BE PLACED ON ALL BLANK CASINGS AT INTERVALS OF NO MORE THAN 40 FEET

Figure 3.2-2c
GENERALIZED BEDROCK AQUIFER MONITOR WELL CONSTRUCTION (DENVER FM. WELL COMPLETED IN FIRST SANDSTONE, ALLUVIUM SATURATED, SANDSTONE AT THE ALLUVIAL-BEDROCK CONTACT)
SOURCE: ESE, 1986

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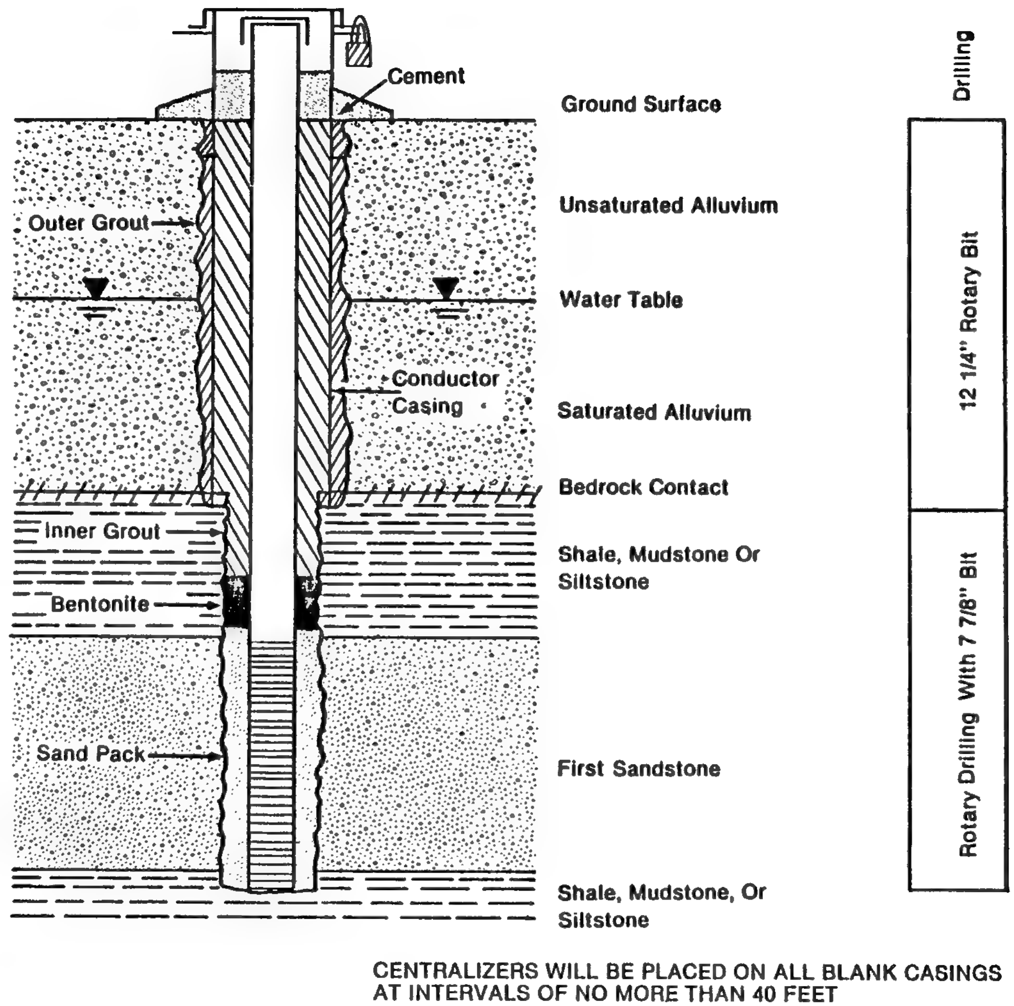

Figure 3.2-2d
GENERALIZED BEDROCK AQUIFER MONITOR WELL CONSTRUCTION (DENVER FM. WELL COMPLETED IN FIRST SANDSTONE, ALLUVIUM SATURATED, SHALE AT THE ALLUVIAL-BEDROCK CONTACT)
SOURCE: ESE, 1986

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For Rocky Mountain Arsenal
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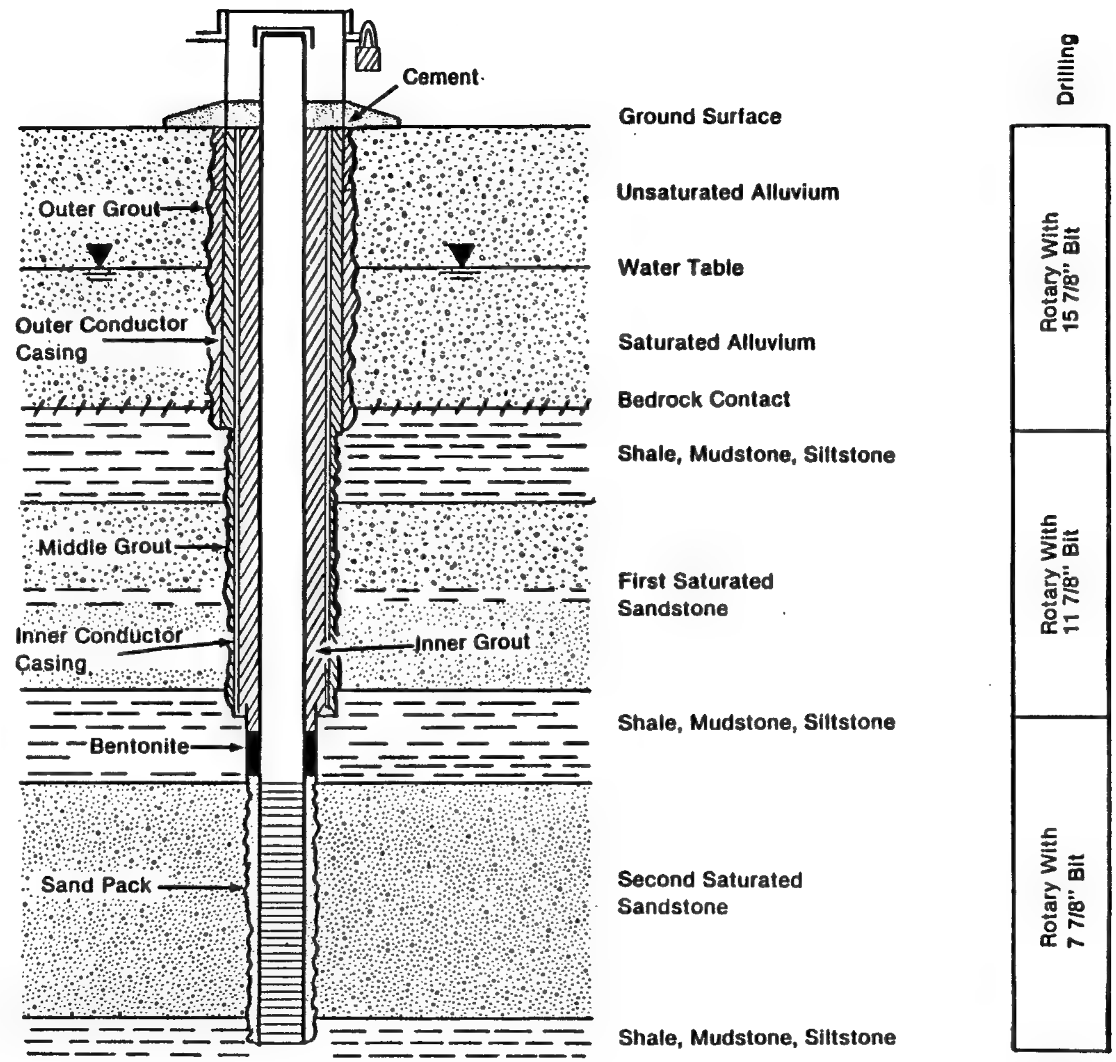

CENTRALIZERS WILL BE PLACED ON ALL BLANK CASINGS AT INTERVALS OF NO MORE THAN 40 FEET

Figure 3.2-2e
GENERALIZED BEDROCK AQUIFER MONITOR WELL CONSTRUCTION (DENVER FM. WELL COMPLETED IN SECOND SANDSTONE, ALLUVIUM SATURATED, SHALE AT THE ALLUVIAL-BEDROCK CONTACT)
SOURCE: ESE, 1986

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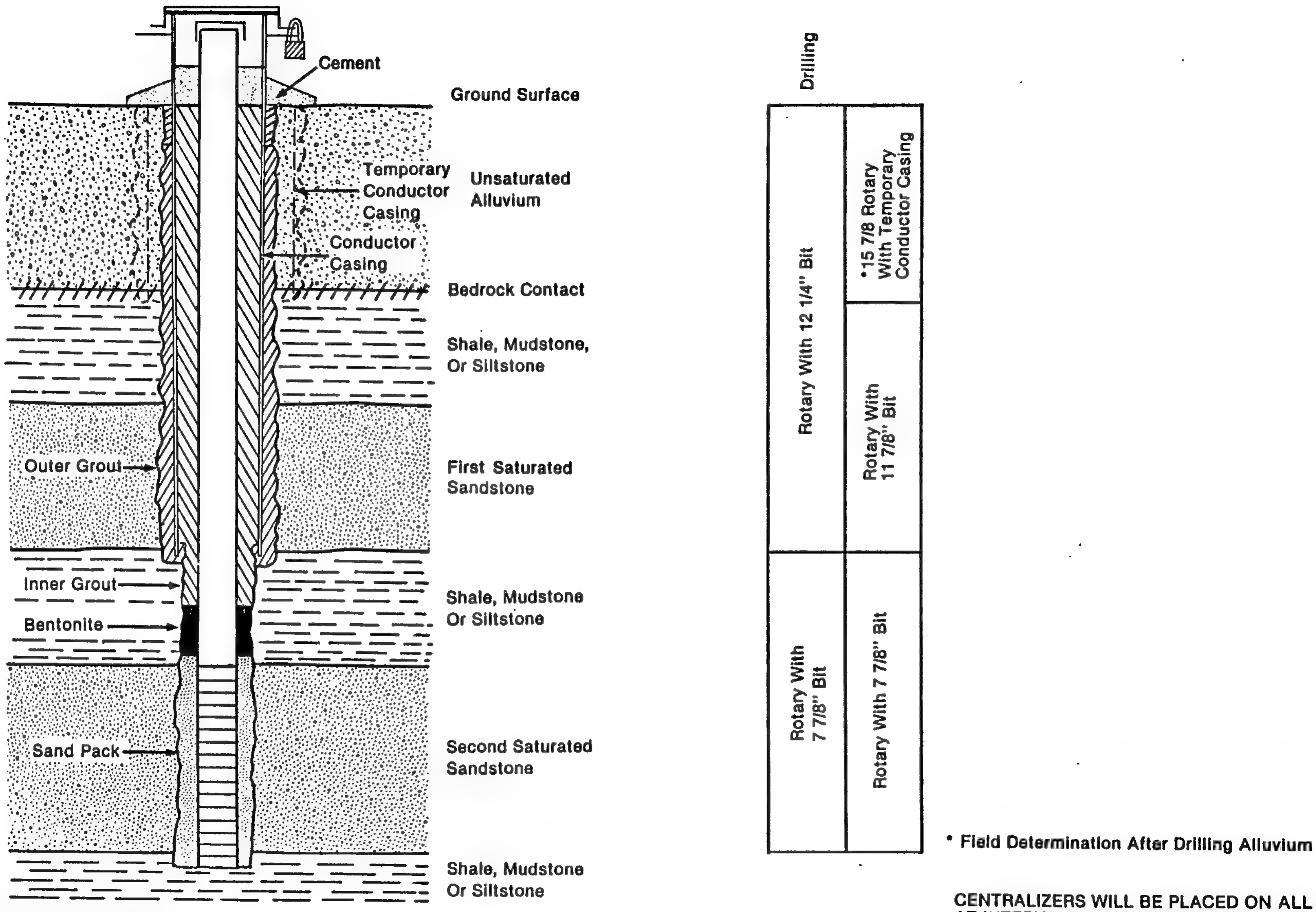

CENTRALIZERS WILL BE PLACED ON ALL BLANK CASINGS AT INTERVALS OF NO MORE THAN 40 FEET

Figure 3.2-2f
GENERALIZED BEDROCK AQUIFER MONITOR WELL CONSTRUCTION (DENVER FM. WELL COMPLETED IN THE SECOND SANDSTONE, ALLUVIUM UNSATURATED, SHALE AT THE ALLUVIAL-BEDROCK CONTACT, FIRST AND SECOND SANDSTONE SATURATED)

SOURCE: ESE, 1986

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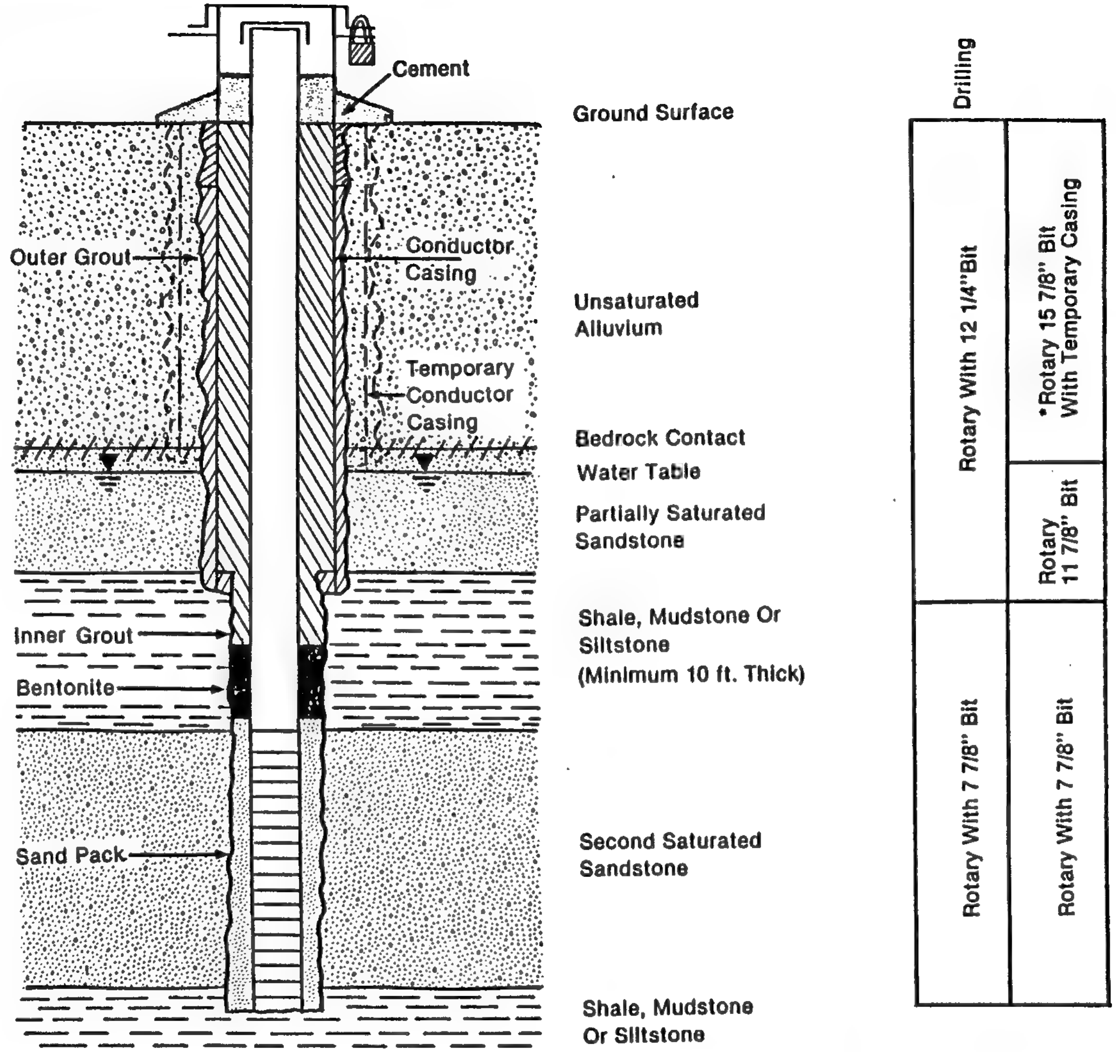
Aberdeen Proving Ground, Maryland



* Field Determination After Drilling Alluvium

CENTRALIZERS WILL BE PLACED ON ALL BLANK CASINGS AT INTERVALS OF NO MORE THAN 40 FEET

Figure 3.2-2g
GENERALIZED BEDROCK AQUIFER MONITOR WELL CONSTRUCTION (DENVER FM. WELL COMPLETED IN THE SECOND SANDSTONE, ALLUVIUM UNSATURATED, SATURATED SANDSTONE AT THE ALLUVIAL-BEDROCK CONTACT)

SOURCE: ESE, 1986

Prepared for:
U.S. Army Program Manager's Office For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

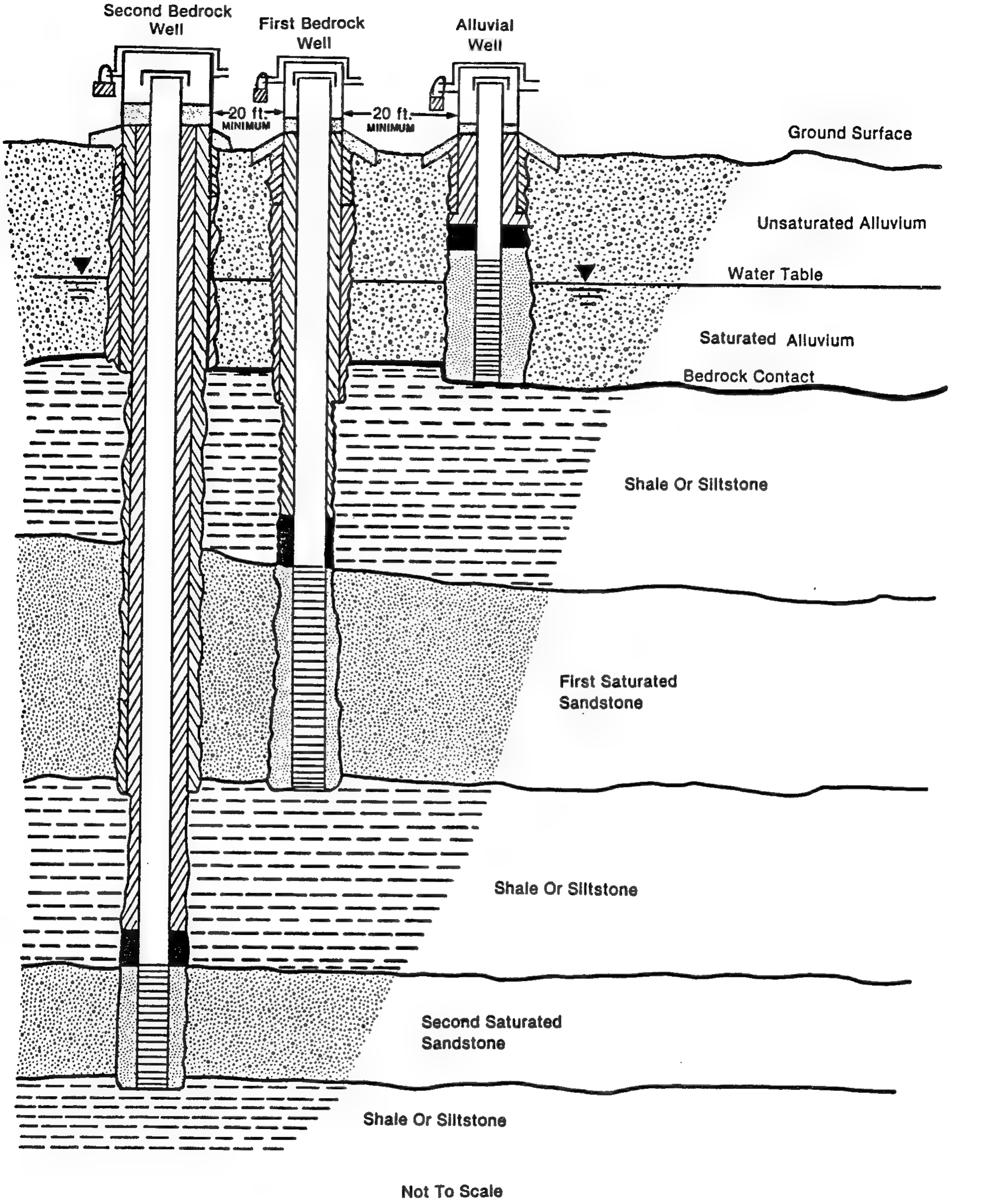


Figure 3.2-3
SCHEMATIC DRAWING OF A TYPICAL CLUSTER WELL INSTALLATION
SOURCE: ESE, 1986

Prepared for:
U.S. Army Program Manager's Office For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

core holes will be drilled at all bedrock well sites to determine lithology. These holes will then be abandoned in accordance with Section 3.4.

3.2.4 WELL SCREENS, CASINGS, AND FITTINGS

Well screen will be commercially fabricated, high-flow, 20-slot (0.020-in) PVC having an ID of 4-in. The bottom of the screen will be fitted with a threaded PVC cap located within 6-in of the screen. The screen will extend throughout the water bearing unit and will be attached to schedule 40 PVC casing by a nonrestrictive threaded type joint. Alluvial wells will be screened 5 ft above the water table. Telescoped casing used to prevent cross-contamination between aquifers will be standard black iron pipe. Prior to installation all screens and casing materials will be decontaminated and stored in plastic. They will be clean and free from foreign matter (adhesive tape, labels, soil, grease, etc.) and will be washed with approved water. Casing tops will be fitted with oversized hand removable caps.

Stainless steel well centralizers will be attached by stainless steel clamps and will be used only on blank casing and above the sand pack. Boreholes containing excessively thick or particulate-laden fluid that might preclude or hinder well installation may be purged with USATHAMA approved water.

3.2.5 SAND PACK

The annular space between the casing/screen assembly and the borehole will be filled with a sand pack to a depth of no less than 5 ft above the well screen. A 1-pint sample will be submitted to the PMO-RMA for approval prior to use on site. It is expected that the material used will be 8- to 12-mesh silica sand from Colorado Silica Sand, Inc. If water is needed to facilitate placement of the sand pack, a minimal amount of approved water will be used. The volume of this water will be recorded for subsequent removal during well development.

3.2.6 BENTONITE SEAL

A bentonite seal 5-ft thick will be placed above the sand pack except where shallow ground water table conditions prevent this. The thickness will be that measured immediately after placement, without allowance for swelling.

The seal will be composed of commercially available bentonite pellets. This material will meet USATHAMA specifications and be approved by PMO-RMA prior to use on the site. Bentonite seals will be placed as shown in Figure 3.2-1 through 3.2-3.

3.2.7 GROUT SEAL

Annular spaces in alluvial monitor wells will be grouted by pumping through a tremie-pipe placed at the bottom of the interval to be grouted or by gravity placement within the hollow-stem auger. The grout will be composed of 20 parts cement to a minimum of 1 part bentonite, and a maximum of 12 gal of water per sack of cement. The annular space between conductor casings in Denver Formation monitor wells will be pressure grouted from the bottom of the casing using Haliburton type techniques. These materials will meet USATHAMA specifications and be approved by PMO-RMA prior to use on site. The grout seal will be inspected for settlement 24 hours after placement and grout will be added, if necessary, to the level of the ground surface.

3.2.8 PROTECTIVE CASING

A lockable protective casing will be set into the grout seal surrounding offpost wells. The casing will be constructed from 8-in-diameter steel pipe, 5 ft long, with a lid capable of being locked. The casing will be cleaned of all foreign matter prior to use. It will extend into the grout to about 3.0 ft below the ground surface and will extend about 2.0 ft above the ground surface. The offpost wells will be padlocked at the time of the installation of the protective casing. After installation, the outside of the protective casing will be painted white, and the well identification will be painted black. All painting will be with a paintbrush and, not, with an aerosol can.

Onpost wells do not require casing. However, protective casing may be used at some onpost sites where there is considerable traffic and a substantial probability of damage.

Aggregate cement will be poured to a depth of about 0.5 ft above the ground surface in the annular space inside the protective well casing and outside the well casing a circular 4-ft-diameter pad 0.5-ft thick will be poured.

A 0.25-in diameter drainage port will be drilled in the protective casing just above the level of the cement collar.

3.2.9 WELL DEVELOPMENT

Upon completion of the well installation, the monitoring wells will be developed at least two weeks prior to sampling. Well development will be conducted by means of either a submersible pump or a bottom discharge bailer, with or without a surge block. A minimum of five times the volume of standing water in the well, sand pack, and annulus will be removed. If any water was added and lost during drilling or completing the well, five times this volume will be removed. The wells will be developed until the water is clear and as sediment-free as possible and any remaining sediment obstructs no more than 5 percent of the total screen length.

Measurements obtained and recorded will include static water levels before and after development, field pH, and conductivity measurements before, during, and after development. For each well, a 1-pint sample of the last water to be removed during development will be collected and retained. Appropriate forms and other pertinent data will be submitted to PMO-RMA or an authorized representative in accordance with USATHAMA Geotechnical Requirements.

3.3 STANDPIPES

Standpipes will be installed around the soil-bentonite barrier to provide a long-term monitoring system for water levels. These wells will either be driven using 1-in or 2-in-inside diameter (ID) stainless steel pipe or drilled using hollow-stem augering or rotary techniques. Drilled wells will utilize 1-in or 2-in ID 20-slot (0.020 in) PVC for well screen. In both cases, blank casing will be extended from the screened interval to 2 ft above the ground surface. A 4-in ID steel casing will be placed in a 3-ft deep grout seal for protection. The tops of the wells will be sealed with PVC caps.

3.4 ABANDONMENT

The abandonment of well sites will be required whenever and wherever the useful purpose of the site or installation is deemed unacceptable. The abandonment of wells will be approved by the Contracting Officer prior to any casing removal, sealing, or backfilling. Once removed, the borehole or monitor well to be abandoned shall be sealed by grouting from the bottom of the bore/well to ground surface. This shall be conducted by placing a grout pipe (tremie pipe) to the bottom of the bore/well (i.e., to the maximum depth drilled/bottom of well screen) and pumping grout through the grout pipe until undiluted grout flows from the bore/well at ground surface. Any open or ungrouted portion of the annular space between the well casing and borehole will also be grouted in the same manner. After grout placement, the grout pipe, augers, and well casing will be removed. When conditions permit, the grout placement and casing removal may be completed incremently so as to constantly maintain 10 ft of grout within the borehole.

After 24 hours, ESE will check the abandoned site for grout settlement. That day, any settlement depression shall be filled with grout and rechecked 24 hours later. This process shall be repeated until firm grout remains at ground surface.

3.5 DISPOSAL OF DRILLING REFUSE

Drilling, installation, development, and testing activities will generate borehole materials and fluids that may be contaminated. These materials will be containerized in 55-gal plastic drums and transported from the field to designated storage or disposal areas at RMA.

Task 32, "Waste Water Disposal", is the task that has the responsibility of handling all containerized wastes that are found to be contaminated. Each individual task has the responsibility of transporting contaminated wastes to a designated staging area and ensuring that all containers are properly labelled. The individual tasks also are responsible for disposing of uncontaminated ground water and soil in accordance with Task 32.

3.6 FIELD DOCUMENTATION

All field personnel will be required to maintain a written record of their daily activities. All records will be kept on prepared forms and will be signed and dated by all field personnel at the end of the day.

The drill site geologist will maintain a Record of Activities at the Drill Site (Figure 3.2-4) on which a time record of all drill site activities will be kept. The drill site geologists will also prepare as necessary a Borehole Summary, Well Construction Summary, Soil/Core Sample Chain-of-Custody, Borehole or Well Abandonment Report, and a Drill Site Geologist Daily Report (Figures 3.2-5 through 3.2-9).

All other field personnel will maintain a Daily Activities Summary (Figure 3.2-10). The geologist logging the soil and core samples will use the Soils Log and Core Log (Figures 3.2-11 and 3.2-12) to prepare detailed descriptions of samples following USATHAMA guidelines. The well development team will record development data on the Well Development Data Form (Figure 3.2-13).

3.7 HYDROGEOLOGIC DATA ACQUISITION

Hydrogeologic data will be required to determine the quantity, direction, and rate of ground water movement. This data will be needed to determine the hydrologic conditions at the NBCS, analyze the design, construction, and performance of the system, and recommend remedial actions for the system. Historically much data has been collected from field and lab tests. This data will be evaluated for its adequacy in coverage and detail as part of the Data Compilation (Section 2.0). Where necessary, additional hydrogeologic data will be acquired using historically proven methods. All data from existing and new lab and field tests will be integrated to fully characterize the aquifers as needed for the system assessment.

3.7.1 AQUIFER TESTS

Aquifer tests are the most accurate method of obtaining representative hydrogeologic data over large areas. In the past, these tests have been

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ENGLEWOOD, COLORADO 80112 • 303/741-0639

PAGE________OF________

RECORD OF ACTIVITIES AT DRILL SITE

Boring Number:__________ Well Number__________ Date:__________

Location:__________ Project Number:__________

Drill Site Geologist:__________

Drill Site Geologist __________ Date __________

Figure 3.2-4
RECORD OF ACTIVITIES AT DRILL SITE

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

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ENGLEWOOD, COLORADO 80112•303/741-0639

BOREHOLE SUMMARY LOG

Borehole ____________________ Well ____________________

Project Name and Location ____________________ Project Number__________

Drilling Company________________ Driller________________ Rig Number__________

Drilling Method(s) ____

____

Size(s) and type(s) of bit(s) ________________________________

Borehole Diameter _____in. _____cm. _____ft. _____cm. to _____ft. _____cm.

_____in. _____cm. _____ft. _____cm. to _____ft. _____cm.

Sampling Methods ____

Total Number Soil Sampling Tubes ____________________

Total Number Core Boxes ____________________

Number of Gallons Lost Drilling Fluid____________________

Date/Time Started Drilling____________________

Date/Time Completed Drilling ____________________

Total Borehold Depth __________ft. __________cm.

Depth to Bedrock __________ft. __________cm.

Depth to Water __________ft. __________cm.

Water Level Determined By?____________________

Borehole Completed as Monitoring Well? ____________________

Date/Time Grouting Completed ____________________

Depth of Tremmie Pipe ____________________

Gallons of Grout ____________________

Materials Used ____________________

Comments____

____

____

Wellsite Geologist ____________________ Date__________

Checked for Grout Settlement on ________________ by________________

Amount of Grout Added ________________________________

All Measurements from Ground Level

Reviewed by ____________________ Date__________

Drill Site Geologist ____________________ Date __________

Figure 3.2-5
BOREHOLE SUMMARY LOG

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

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ENGLEWOOD, COLORADO 80112 • 303/741-0639

WELL CONSTRUCTION SUMMARY

Borehole ____________________ Well ____________________

Project Name and Location ____________________ Project Number __________

Drilling Company __________ Driller __________ Rig Number __________

Drilling Method(s) ____________________

____

Borehole Diameter _____ in. _____ cm. _____ ft. _____ cm. to _____ ft. _____ cm.

_____ in. _____ cm. _____ ft. _____ cm. to _____ ft. _____ cm.

Size(s) and types of Bit(s) ____________________

____

Size and Type PVC ____________________

Total Borehole Depth _____ ft. _____ cm.

Depth to Bedrock _____ ft. _____ cm.

Depth to Water _____ ft. _____ cm.

Water Level Determined By ____________________

Length Plain PVC (total) _____ ft. _____ cm.

Length of Screen _____ ft. _____ cm.

Total Length of Well Casing _____ ft. _____ cm.

PVC Stick Up _____ ft. _____ cm.

Depth to Bottom of Screen _____ ft. _____ cm.

Depth to Top of Screen _____ ft. _____ cm.

Depth to Top of Sand _____ ft. _____ cm.

Depth to Top of Bentonite _____ ft. _____ cm.

Sampling Method(s) ____________________

Date/Time Start Drilling ____________________

Date/Time Finish Drilling ____________________

Date/Time Start Completion ____________________

Date/Time Cement Protective Casing ____________________

Materials Used ____________________

Plain PVC ____________________

Slotted PVC ____________________

Bentonite Pellets ____________________

Bentonite Granular ____________________

Cement ____________________

Sand ____________________

Water added during completion ____________________

Water added during drilling ____________________

Total Gallons of water added ____________________

Drill Site Geologist ____________________ Date ____________________

Date/Time/Personnel Internal Mortar, Cement Pad, and Weep Hole Installed ____________________

Date/Time/Personnel Casing Painted ____________________

Date/Time/Personnel Numbers Painted ____________________

Materials Used ____________________

Top of Protective Casing to Top of PVC _____ ft. _____ cm.

Top of Protective Casing to Weep Hole _____ ft. _____ cm.

Top of Protective Casing to Internal Mortar _____ ft. _____ cm.

Top of Protective Casing to Top ofCement Pad _____ ft. _____ cm.

Top of Protective Casing to Ground Level _____ ft. _____ cm.

COMMENT/NOTES

____

____

____

____

Reviewed By ____________________ Date __________

Drill Site Geologist ____________________ Date __________

Figure 3.2-6
WELL CONSTRUCTION SUMMARY

Prepared for:
U.S. Army Program Manager's Office For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

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SOIL/CORE SAMPLE SHEET

CHAIN OF CUSTODY

BORE: ______________

Core/Sample Interal (Ft.)	Recovery (Ft.)	Box/Sample Tube Number	Comments

Relinquished By:(Name/Company/Date/Time) Received By:(Name/Company/Date/Time)

1. ______________
2. ______________
3. ______________
4. ______________

Figure 3.2-7
SOIL CORE SAMPLE SHEET

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For Rocky Mountain Arsenal
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BOREHOLE	

SHEET ______ OF ______

BOREHOLE OR WELL ABANDONMENT REPORT

BORING NUMBER: ______ ______ DATE ______

PROJECT NUMBER: ______ TASK NUMBER: ______

PROJECT DESCRIPTION: ______

BEGAN DRILLING: ______ ENDED DRILLING: ______

	DEPTHS	DATES MEASURED
Total Depth:		
Sampled to:		
To Water:		
To Mud:		
Caved Hole:	______ to ______	
	______ to ______	

ITEMS LEFT IN THE HOLE

Description: ______ Depth: ______

GROUT BACKFILL

Initial Quantity: ______ Date: ______

Quantity Added: ______ Date: ______

______ Date: ______

REASON FOR ABANDONMENT: ______

Figure 3.2-8
BOREHOLE OR WELL ABANDONMENT REPORT

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U.S. Army Program Manager's Office For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

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DRILL SITE GEOLOGIST DAILY REPORT

Geologist: ____________________ Date: ____________

Borehole/Well: ____________________ Task: ____________

Drill Rig/Drill Crew: ____________________

Daily Crew Mobilization: ____________________ Move & Set Up: ____________

Well Completion: ____________________ Decon: ____________

Down Time: ____________________

____

Stand By: ____________________

____

	Feet Sampled	Feet Recovered	% Recovery
Continuous Soil Sampling:			
Continuous Rock Core:			

Auger Drilling: ____________________ Rotary Drilling: ____________

____

Corehole Reaming: ____________________ Materials Supplied By Driller: ____________

____

Total Hours Drill Site Geologist: ____________________

Comments: ____________________

____

____

____

____

____

Driller/Date: ____________________

Drill Site Geologist/Date: ____________________

Reviewed By/Date: ____________________

Figure 3.2-9
DRILL SITE GEOLOGIST DAILY REPORT

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PAGE________OF________

DAILY ACTIVITY SUMMARY

Personnel____________________ Date____________________

Time Start____________ Time Stop____________ Total Hours____________

Borehole/Well	Task	Activity/Materials Used	Hours

Personnel	Date	Reviewed By	Date

Figure 3.2-10
DAILY ACTIVITY SUMMARY

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

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SHEET________ OF________

Borehole:____________________ Well Number:____________________

Depth – Feet	Tube Number Tube Interval	Recovery	Sample Number	Sample Interval	Unified Soil Classification	SOILS LOG Description

Drill Site Geologist:____________________ Date:____________

Reviewed By:____________________ Date:____________

Figure 3.2-11
SOILS LOG

Prepared for:
U.S. Army Program Manager's Office For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

ESE, Inc. CORE LOG By ________ Date ________ BORE ________ Well(s) ________ Page ___ of ___

BOX no.	DEPTH	Rec. Int.	Weath.	Structure / Bedding		Hard-ness	Perm.		Mineralogy		Color	Texture / Grain Size	Lith. Char.	Lith. Class	Description / Comments
				Angle	Desc.		1°	2°	Min.	Habit		cl st sd gr mm			
			U S			S H	L H	L H			M G	.01 1.0 100		Ft	CM (Scale 1"=________ ft)
															Reviewed By ________ Date ________

ESE, Inc. BORE ________ WELL(S) ________

Figure 3.2-12
CORE LOG

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SHEET ______ OF ______

WELL DEVELOPMENT DATA

Bore ______________ Well ______________

Project ______________ Project Number ______________

Date(s) Developed ______________ Date Installed ______________

Personnel (Name/Company) ______________ Well Diameter (I.D.) ______________ in.

______________ Anulus Diameter ______ in. ______ ft. to ______ ft.

Rig Used ______________ ______ in. ______ ft. to ______ ft.

Pump (Type/Capacity) ______________ Screen Interval ______ ft. to ______ ft.

Bailer (Type/Capacity) ______________ ______ ft. to ______ ft.

Water Source ______________ Casing Height (Above G.L.) ______________ ft.

Measured Well Depth TOC (Initial) ______ ft. Bottom of Screen (Below G.L.) ______________ ft.

(Final) ______ ft.

Water Level TOC/Date/Time (Initial) ______________

(after 24 hrs.) ______________

Feet of Water in Well ______ ft. x ______ gallons/foot = ______ gallons casing/anulus volume

Drilling Fluid Lost ______________ gallons One Purge Volume ______________ gallons

Purge Water Lost ______________ gallons Minimum Purge Volume ______________ gallons

Added Water ______________ gallons Total Purge Volume ______________ gallons

Casing/Anulus Volume ______________ gallons Volume Measured By ______________

Surge Technique ______________

Calibration: pH Meter Used: ______________

pH 7.00 = ______ at ______ °C, pH 10.00 = ______ at ______ °C

Conductance Meter Used: ______________

Standard ______ umhos/cm at 25°, Reading ______ umhos/cm at ______ °C

Purge Volume	Time	Temp. °C	pH	Conductance at 25°C	Physical Characteristics (clarity, odor, sand content, color)
Initial					
Final					

Remarks: ______________

____

____

Collected by ______________
Signature Date

Checked by ______________
Signature Date

Figure 3.2-13
WELL DEVELOPMENT DATA

Prepared for:
U.S. Army Program Manager's Office For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

used successfully to characterize the hydrogeology near the NBCS (Vispi, 1978; Black & Veatch, 1980; May, 1980; ESE, Inc., 1986b).

Several pumping tests and slug tests have been performed on the alluvial aquifer in Sections 23 and 24 upgradient from the NBCS as well as on sandstones in the Denver Formation near the NBCS. Pumping tests have been proposed for approximately five wells offpost in Task 39 to estimate aquifer transmissivity and other hydrogeologic parameters. Where appropriate, this data will be applied to the area of interest in the NBCS. In the past, pumping tests have concentrated on the aquifers upgradient from the system. The suspected problems with recharge at the NBCS indicate that some pumping or recharge tests may be required downgradient from the system to accurately characterize the transmissivity in recharge areas.

Hydrogeologic data have historically been collected from the Denver Formation sandstones using both pumping tests and slug tests (Black & Veatch, 1980; May et al, 1980; ESE, Inc., 1986b). Where appropriate, additional slug tests or pumping tests on the Denver sandstones will be considered if this data seems necessary for an overall assessment of the system.

In order to characterize the local conditions within the NBCS, especially to see if hydraulic properties may have been altered because of the operation of the system, tests on existing production wells, such as well recovery tests for individual dewatering or recharge wells can be done as part of the operational evaluation of the system.

Data gathered from all of these tests will be analyzed using standard techniques. Values of the storage coefficient and transmissivity of aquifers can be calculated from test data by solving the differential equation applicable to the transient flow problem. The Theis Method is the most common analytical technique used to solve the governing equation and will be used.

The specific number, type, and locations of aquifer tests will depend on Phase I of the Data Compilation portion of this task. Based upon the findings of the review, specifics of the plans will be outlined in Letter Technical Plans and sent out for review.

Waste water from the pump tests will be handled as directed by PMO-RMA and Task 32. The alternatives being considered at present is running the water through the NBCS.

3.7.2 LABORATORY TESTS

Permeability investigations are proposed for samples obtained from the drilling program to augment the field data. Selected samples, based on the variability of materials encountered during the drilling program will be tested to obtain a range of permeability values for individual, characteristic borehole materials. These tests are proposed primarily for barrier samples and fractured bedrock samples beneath the barrier.

The method suggested for determining hydraulic conductivity are primarily inspection of samples and laboratory permeability tests. Laboratory permeability tests may provide approximate data on aquifer transmissivity. However, this method is conducted on a disturbed sample and the values obtained may not be representative of actual field conditions. These tests are generally conducted so that the permeability is measured in the vertical direction. This data does not usually represent the permeability in the primary direction of ground water flow, the horizontal direction, which is the hydraulic conductivity of primary importance in this ground water study.

3.7.3 WATER LEVEL MEASUREMENTS

Water levels will be measured under this task. The data will be used to construct maps showing horizontal and vertical gradients, to help analyze the hydrogeologic response to system operation, and to assess the integrity of the barrier. Details of the methods to be used are outlined in Section 3.8.3.

3.8 SAMPLING PROGRAM

The sampling portion of the Geotechnical Program will address the acquisition of physical samples of several media on which various physical laboratory tests and chemical analyses will be conducted. Samples collected as part of other tasks will be used where appropriate to minimize duplication by this task.

3.8.1 SAMPLING OF FRACTURED ROCK

Sampling of rock for fracture analysis is proposed for the drilling program. Discussion of the acquisition of these samples has been addressed in Section 3.2.2. This sampling is considered necessary to assess the hydraulic conductivity of fractured Denver Formation below the soil-bentonite barrier. For this purpose angled coreholes are recommended to collect oriented core for fracture analysis because vertical holes may not intersect vertical fractures.

3.8.2 BARRIER SAMPLING

Physical samples of the barrier will be taken based on review of water levels and contaminant distributions around the barrier. High downgradient contaminant concentrations or low head differences across the soil-bentonite trench may indicate zones of relatively high permeability within the barrier. These indicators will be examined historically and supplemented with new data before a sampling program is initiated.

It is anticipated that vertical bores will be drilled using a split-spoon sampler with a small diameter hollow-stem auger. This procedures should give the sample size necessary to run physical laboratory tests and conduct chemical analyses while causing minimal disturbance to the barrier. All boreholes will be filled immediately with a compatible bentonite-soil mixture to seal the holes and minimize increased flow through the wall.

3.8.3 WATER SAMPLING

A water sampling and water level monitoring program will be performed in the project area. The program will concentrate on newly completed wells. Methodology of sampling will conform to the established and approved

procedures and protocol used in ongoing tasks utilizing the same field crews, equipment, schedules, and management teams. Rather than repeat the extensive protocol here, the reader is referred to the Technical Plan for Task 4 (ESE, Inc., 1986a, RIC#86238R08) for the details of water sampling and monitoring. Sections 3.8.3.1 and 3.8.3.2 which follow briefly summarize sampling procedures and chain-of-custody and are excerpted from the Task 4 Technical Plan.

Two sets of water samples will be collected from an anticipated 35 wells. Each sample set will be collected over a short time span (1 to 2 weeks) to characterize contaminant migration at "instantaneous" points in time. (The long term evaluation of contaminant migration through the barrier is covered by Task 25). Two sample sets are needed for comparison purposes and to allow aquifer re-equilibration after new well installation.

Water level monitoring will be on a more frequent basis than sampling to discern fluctuations in the piezometric surfaces in response to the operation of the system. Frequency will be determined from evaluation of the operation of the system. The number of water level data points will be much larger than water quality sample points as well.

3.8.3.1 Sampling Procedures

Ground water sampling methodology and techniques adhere to USATHAMA Geotechnical Requirements with respect to decontamination, collection, preservation, shipment, and chain-of-custody requirements. Further discussion of these aspects of sample collection is provided in the Task 4 Technical Plan (ESE, 1986a).

The following is a summary of the sampling procedures to be used in the investigative program:

- Sampling crews receive labeled sample kits from Field Team Coordinator;
- Record well number, date, pertinent information (e.g., weather and well conditions), station elevation, casing diameter, screened

interval, and field equipment identification (manufacturer and ID number);

- Measure and record well stickup, depth to water, total well depth, HNU readings, and calculate well casing volume;
- Lower submersible pump to a few feet below the maximum drawdown or to the bottom of the well. If well is constricted above water level and pump will not pass, lower bailer to a few feet below water level. Record depth to pump or bailer;
- Pump or bail five casing volumes out of well. Measure and record time, pH, conductivity, and temperature after each well volume. Measure and record HNU readings by obtaining frequent background, well head, and discharge water values. If well is located within a known contamination plume or if HNU readings are obtained above background levels, discharge water will be collected in barrels. Otherwise water may be discharged on the ground at least 50 ft from the well head;
- Measure and record pumping rate, total pumping time, and total volume purged;
- Sample will be taken from the inline system, using care to verify that flow rate is maintained during sampling to prevent volatile stripping;
- If the well is dewatered, remove pump. Sample within 24 hours using bottom filling and discharging stainless steel bailer. Measure pH conductivity, and temperature of sample obtained from bailer being used for sampling;
- Record time and measured values on sampling sheet, in field notebook, and on sample labels;
- Decant portion of water into sample bottles; cap bottles, agitate bottles, and discard water. Fill rinsed sample bottles directly from bailer. Record sample depth;
- Place bottles in ice chest;
- Complete chain-of-custody forms;
- Sign and date well sampling form; and
- Seal cooler and ship samples.

All pertinent data obtained during ground water sampling will be recorded on Field Sampling Data sheets and kept in a bound field notebook. The information recorded for each well sampled includes:

- Well number;
- Date and time (24-hour system);
- Pertinent observations (e.g., weather, well condition);
- Station elevation;
- Well stickup;
- Static water level and well depth;
- Casing diameter;
- Number of gallons per casing volume;
- Screened interval;
- HNU readings;
- Pump depth, measured pumping rates, total pumping time, and total volume of water removed;
- Characteristics of the water (color, odor, etc.);
- Measurements of pH, temperature, and conductivity;
- Identification of field equipment;
- Sampling description (number of bottles, sample fractions, sample depth);
- Field notebook number; and
- Signature of samplers and field team coordinator.

Records will be kept of all wells visited, including those found to be dry or constricted such that sampling was impossible. Dry wells include those wells with the water level below the bottom of the screened interval.

3.8.3.2 Sample Shipment/Chain-of-Custody

The ESE Site Geologist will serve as Sampling Team Leader and will supervise and assist in the sampling of all ground water and surface water sampling stations. Samples will be labelled, filtered, and preserved in the field. A log sheet will be filed and signed by the Site Geologist to serve as a check that all samples and operations are complete. Samples will be packed in styrofoam ice chests with sufficient ice to maintain less than 4 degrees

centigrade (°C) during transport to the laboratory. The ice will be double-bagged to prevent contact of the melt water with the samples. All samples will be checked for integrity and lid closure to prevent leakage.

The sampling logistics will occur as follows. The time elapsed between the first sample collection and initiation of processing in the laboratory will be approximately 24 to 30 hours, based on transportation schedules.

The Chemical Analysis Supervisor will be notified of sample shipment and estimated time of arrival. The Chemical Analysis Supervisor or a designate will receive the sample, verify the contents, and sign the log sheet. Samples are stored at ESE in a 4°C refrigerator under the control of the Data Management Supervisor in the Sample Control Center. The procedures for sample fraction control during analysis are described in the Data Management Plan in Volume I of the Task 1 Technical Plan.

Any sample which is leaking, any situations in which holding times are not met, or any other problems which may compromise the data, are noted at the time of receipt of the samples and reported to the Quality Assurance (QA) Supervisor for development of corrective action. The QA Supervisor verifies the chain-of-custody record of each sample set.

3.9 BARRIER TESTS

The testing of the physical condition of the bentonite slurry wall is an option to be considered if other investigative means point to problems with the wall's integrity. Discussions of the relative merits and safety of the various tests is included in Section 8.3 Barrier Assessment. The following program is recommended based on the limited funds available for this project. However, one or more of the methods outlined in Section 8.3 may be considered if the scope-of-work for the assessment is modified at a later date.

3.9.1 LABORATORY TESTS

Physical sampling of the barrier will be directed by review of hydrological and contamination data as described in Section 3.8.2. Several laboratory

tests are recommended for barrier samples. In addition to standard laboratory permeability tests and grain size analysis, various techniques may be utilized to determine the extent of any chemical and/or physical deterioration of the soil-bentonite mixture. X-ray diffraction coupled with chemical analysis could be used to characterize the composition of montmorillonite and to determine if mineralogical degradation has occurred through exposure to contaminants.

3.10 SURVEYING

Upon completing the installation of the final well, each well location, elevations of the ground surface, and the top of the well casing will be surveyed. Well locations will be accurate to within 3 ft using State Plane coordinates. Elevations will be surveyed to within 0.1 ft using the National Geodetic Vertical Datum of 1929.

Well identification numbers, map coordinates, and elevations will be recorded in a field log book and submitted to USATHAMA. A metal tag stamped with these data will be permanently attached to each protective casing.

4.0 CHEMICAL ANALYSIS

The objective of the analytical program is to provide PMO-RMA with reliable, statistically supportable, and legally defensible chemical data regarding type and level of ground water contamination in the area of the North Boundary Containment System. To achieve this goal a schedule of the analytes previously detected near the boundary systems has been chosen. This analyte schedule was based on the contaminant distribution data from Task 4 (ESE, 1986a, RIC#86238R08) and the first quarter results from Task 25 (ESE, 1987, RIC#87014R24) which are the most recent ground water quality data. The schedule will include 6 organosulfur compounds, 6 volatile aromatics, 8 organochlorine pesticides, DBCP, DCPD, MIBK, DIMP, DMMP, 12 volatile organohalogen compounds and 4 inorganic parameters (Table 4.0-1). Up to four additional inorganic parameters may be proposed via a Letter Technical Plan to help assess possible communication between alluvial and bedrock aquifers. These analytes are also denoted in Table 4.0-1.

ble 4.0-1. Chemical Analysis - Task 36 (Page 1 of 2)

Analysis/Analytes	Hold Time	Level of Certification	Reference Methods	Method
Organochlorine Pesticides		Quantitative	EPA 608	CAP-GC/ECD
Aldrin	Extract as quickly as possible (no more than 7 days). Analyze within 30 days of extraction.			
Endrin				
Dieldrin				
Isodrin				
Hexachlorocyclopentadiene				
p,p′-DDE				
p,p′-DDE				
Chlordane				
Volatile Organohalogens		Quantitative	EPA 601	PACK-GC/Hall
Chlorobenzene	14 days			
Chloroform	14 days			
Carbon Tetrachloride	14 days			
trans-1,2-Dichloroethylene	14 days			
Trichloroethylene (TCE)	14 days			
Tetrachloroethylene	14 days			
1,1 Dichloroethylene	14 days			
,1 Dichloroethane	14 days			
1,2 Dichloroethane	14 days			
1,1,1 Trichloroethane	14 days			
1,1,2 Trichloroethane	14 days			
Methylene Chloride	14 days			
Organosulfur Compounds		Quantitative		PACK-GC/FPD-S
P-Chlorophenylmethylsulfone ($PCPMSO_2$)	Extract as quickly as possible (no more than 7 days.) Analyze within 30 days of extraction.			
P-Chlorophenylmethylsulfoxide (PCPMSO)				
P-Chlorophenylmethylsulfide (PCPMS)				
1,4-Dithiane				
1,4-Oxathiane				
Dimethyldisulfide (DMDS)				
Volatile Aromatics		Quantitative	EPA-602	CAP/Hall
Benzene	14 days			
Toluene	14 days			
Ethyl benzene	14 days			
m-xylene	14 days			
o,p-xylene	14 days			

Table 4.0-1. Chemical Analysis – Task 36 (Page 2 of 2)

Analysis/Analytes	Hold Time	Level of Certification	Reference Methods	Method
DCPD/MIBK		Quantitative	EPA 608	CAP-GC/FID
Dicyclopentadiene/ Methylisobutylketone	Extract as quickly as possible (no more than 7 days). Analyze extract within 30 days of extraction.			
DIMP/DMMP		Qualitative	EPA 622	PACK-GC/FPD-P
Diisopropylmethylphosphonate/ Dimethylmethylphosphonate	Extract as quickly as possible (no more than 7 days). Analyze within 30 of extraction.			
DBCP		Quantitative		CAP-GC/ECD
Dibromochloropropane	14 days			
Inorganics		Quantitative		
Arsenic			*EPA 206.2	Graphite Furnace
Chloride	28 days		EPA 200	Inductively Coupled Plasma
Fluoride			EPA 300	Ion Chromatograph
Sulfate				
* Additional (Optional) Inorganics		Quantitative		
Sodium	6 months		EPA 273.1	
Calcium			EPA 215.1	
Magnesium			EPA 242.1	AA-FLAME
Potassium			EPA 258.1	AA-FLAME

Source: ESE, 1985.

5.0 QUALITY ASSURANCE

Quality Assurance for Task 36 will be consistent with the Field/Laboratory QA Plan developed for Task 1 activities. The plan is project specific and describes procedures for controlling and monitoring sampling and analysis activities as required under Task 36. As designed, the Field/Laboratory QA Plan will ensure the production of valid and properly formatted documentation concerning the precision, accuracy, and sensitivity of each method used for USATHAMA sampling and analysis efforts. The plan is presented in Appendix A of the Task 1 Technical Plan (ESE, 1985, RIC#85127R07). Specific RMA QA/Quality Control (QC) requirements are detailed in Section 5.0 of the same documents.

All tasks assigned under Contract DAAK11-84-D-0016 for "Litigation Technical Support and Services--Rocky Mountain Arsenal" require compliance with the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA) QA Program of April 1982. The current plan is based on and, in general, complies with this USATHAMA QA Program. Deviations from USATHAMA QA procedures, where they occur, have been approved by USATHAMA and are indicated as deviations in the text. Specific details and deviations from the general plan, if any, for a certain task or survey will be described in detail in the Task Sampling and Analysis Plan or test plans. This plan will be implemented by ESE and all subcontractors performing sampling and analytical services.

The specific objectives of the QA/QC plan are to describe in general detail the processes for controlling the validity of the data generated in the sampling and analysis efforts; the methods and criteria for detection of out-of-control situations; steps to be taken to provide timely corrective action; and how such actions will be reported and documented. The Project QA/QC Plan also supports the Data Management Plan by providing documentation of the limits of precision, accuracy, and sensitivity of all analytical systems generating data and by providing mechanisms for documentation of the validity of all reported data.

Some survey tasks may require the development and documentation of certain semiquantitative and quantitative analytical methods for all phases of the project. The analytical systems controls and data validation procedures described in the QA/QC plan will be employed to ensure valid, properly formatted data defining the precision, accuracy, and sensitivity of each method.

5.1 QA ORGANIZATION AND RESPONSIBILITIES

This QA/QC Plan functions according to the USATHAMA central-laboratory/ field-laboratory concept. ESE and its subcontractor laboratory MRI, act as the field laboratories, which are monitored by the USATHAMA Central Laboratory QA Coordinator. The overall QA/QC organization is shown in Figure 5.1-1. The function of the plan and QA responsibilities of each of the project participants are outlined in the following subsections.

Figure 5.1-1 depicts the manner in which the Project QA Supervisor monitors the conduct of the sampling and analytical effort. The Project QA Supervisor is not directly subordinate to anyone responsible for sampling and analysis and reports only to the Project Director. The Project QA Supervisor oversees the performance of the QA/QC Coordinator in the ESE and MRI laboratories. The Project QA Supervisor and QA/QC Coordinators (Project QA Staff) monitor the chemical analysis effort in their respective laboratories to ensure compliance with USATHAMA QA requirements and those of the Project QA/QC Plan. The Project QA staff also audit and monitor field sampling activities.

Field Quality Control procedures for this task will be consistent with EPA and USATHAMA approved methodologies. A summary of these procedures for all trip blanks, rinseate blanks, field blanks, and duplicates are summarized in Table 5.1-1.

The general manner in which the QA/QC Plan functions in each laboratory in terms of data review and monitoring is shown in Figure 5.1-2. The analyst performs the analysis of samples and control samples and plots QC sample results on control charts. The data are then processed through the Data

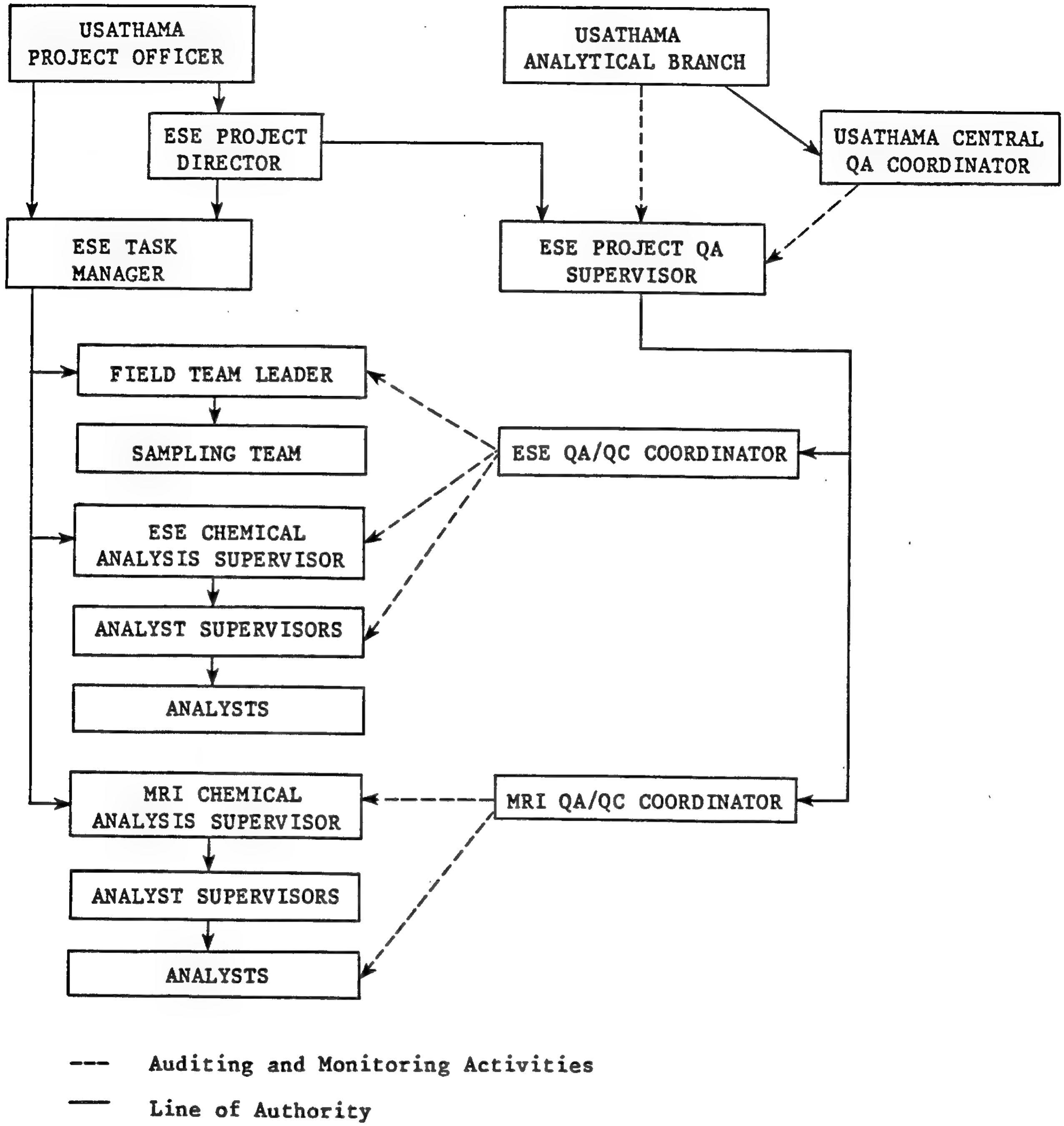


Figure 5.1-1
PROJECT QA/QC ORGANIZATION
SOURCE: ESE, 1985

Prepared for:
U.S. Army Program Manager's Office For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

Table 5.1-1. Field QA/QC Procedures

QA Sample Type	Analtyical Method*	Required Frequency	Preparation
Volatile Trip Blank	W8, Y8	1 paint can with 3 volatile septum vials per week, each week samples for GC analysis are collected.	Transport filled blank volatile septum vials to field, open paint can and return to laboratory with samples.
Rinseate Blank	S8, U8, T8, W8, Y8, X8, K8, R8, Q8	1 suite per week, each samples are submitted	Decontaminate bailer used to collect samples. Pour deionized water into cleaned bailer, then transfer to sample bottles. Perform while onsite. Not applicable if dedicated bailer is used.
Field Blank	S8, U8, T8, W8, Y8, X8, K8, Q8, R8	1 suite per week, each week samples are submitted	Pour organic free deionized water directly into sample bottles. Perform while onsite.
Duplicates	S8, U8, T8, W8, Y8, X8, K8, R8, Q8	1 suite per week, each week samples are submitted	Collect 2 suites of sample bottles while onsite.

* See Table 2.3-1 on Pages 2-14 through 2-16 in the Task 4 Report.

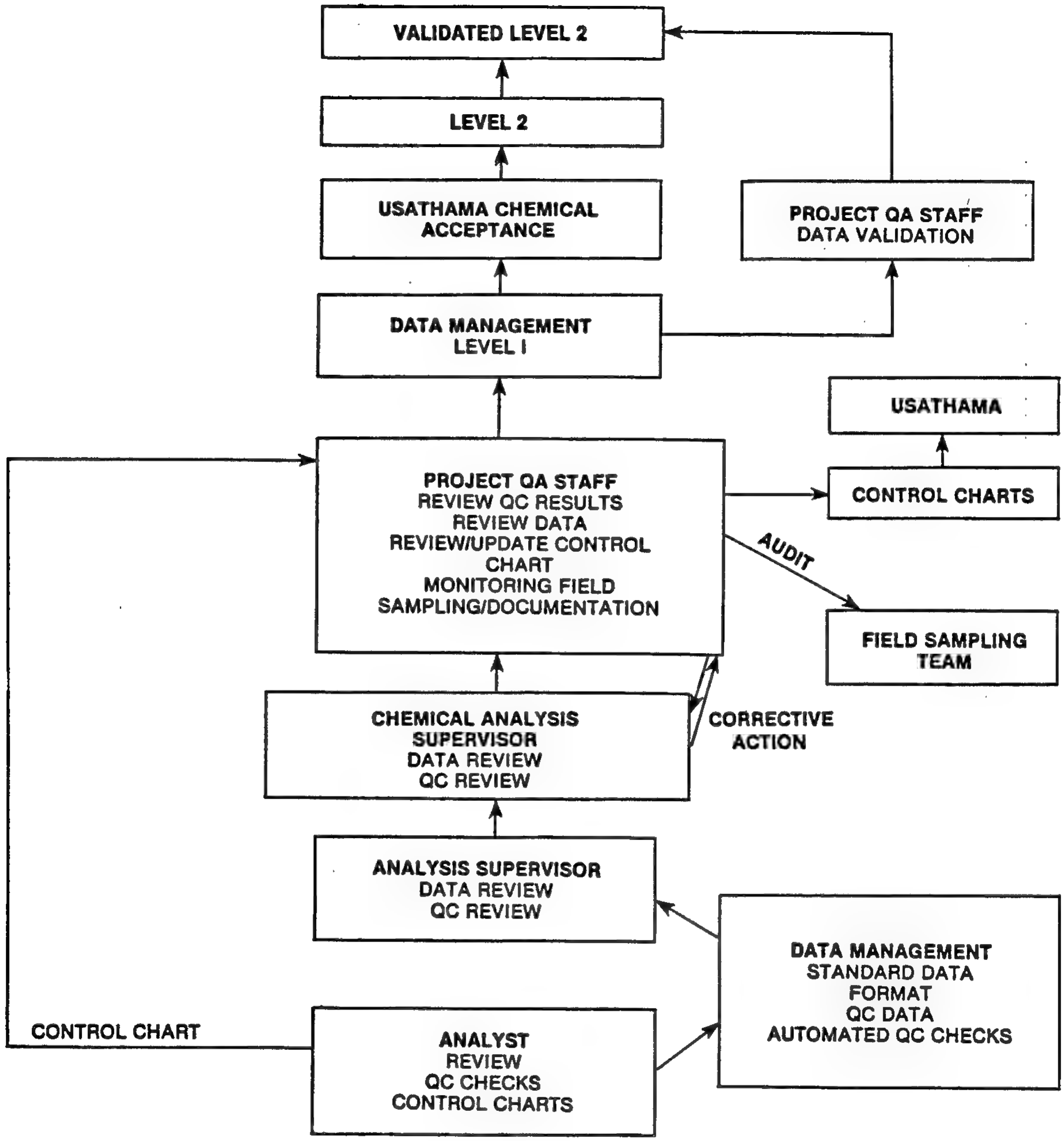


Figure 5.1-2
QA/QC PLAN FUNCTIONS
DATA FLOW AND QC CHECKS
SOURCE: ESE, 1985

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

Management System, where automated QC checks are performed, and the data are presented in standard laboratory and USATHAMA format. The Analyst Supervisor then reviews and approves the data. The Task Chemical Analysis Supervisor then reviews and approves the data and QC results and submits the data batch to the Project QA staff for review. The Project QA staff review and data and monitors QC results and compliance with QA Plan requirements. The data may be returned to the Chemical Analysis Supervisor at this time for any necessary action to correct QC deficiencies.

The Project QA staff are also responsible for updating and reviewing control charts. After QA/QC review, the data batch is returned to the Data Management System for final processing, storage, and transmittal to the USATHAMA Installation Restoration Data Management System (IR-DMS). After entry into the IR-DMS at Level 1, the USATHAMA Chemical Acceptance Program is applied to the data. After the data batch passes the Chemical Acceptance program, the data may be elevated to Level 2 into the IR-DMS. After the data are in Level 1, the Project QA staff begin the process of validation of the chemical data. The validation process verifies the accuracy and transcription of a data subsample. When the validation process is completed, the Level 2 data are designated as validated in the IR-DMS system.

The Project QA Supervisor and QA/QC Coordinator monitor the field sampling effort by regulating the logging-in of samples, checking copies of field notebook entries and logsheets, and observing field sampling procedures and reporting any inconsistencies and/or omissions to the Field Team Leader. The QA Supervisor also monitors the QC and calibration data submitted to support field tests and analysis.

6.0 DATA MANAGEMENT PLAN

Data for Task 36 will be handled according to the Data Management Plan in Volume I of the Task 1 Technical Plan (ESE, 1985, RIC#85127R07), contract Number DAAK11-84-D-0016. As outlined in the plan, field data will be entered into the microcomputer network in the ESE Denver Office and transmitted to the ESE Gainesville Office via telephone modem. Field data will be transferred to IR-DMS, subjected to the Geotest data check routine, validated, and placed into Level 2. Ground water chemical sample number assignments, labels, and logsheets will be made in Denver and given to the sampling team. Samples shipped to laboratories will follow chain-of-custody procedures described in the Task 1 Technical Plan (ESE, 1985, RIC#85127R07). Data from laboratory analyses will be entered into the ESE Prime computer, incorporated with certification and field data, and formatted into files according to the IR-DMS User's Guide. After validation, chemical files will be sent to the Univac via telephone modem from ESE Gainesvile, run through the data-checking routine, and elevated to Level 2.

7.0 SAFETY PROGRAM

The purpose of the safety program described in this section is to summarize the safety, accident, and fire protection standards and procedures and to outline standard operating procedures to ensure the safety of all ESE and subcontractor personnel performing Task 36 activities. Responsibilities, authorities, and reporting procedures designated for Task 36 are identical to those in Section 7.0 of the Task 1 Technical Plan (ESE, 1985, RIC#85127R07).

The program addresses all of the requirements of DI-A-5236B and fully complies with requirements of the Occupational Safety and Health Act (OSHA) and U.S. Army Material Development and Readiness Command (DARCOM) Regulation 385-100, Army Regulation (AR) 385-10, and Department of Army Pamphlet (DA-PAM) 385-1 for all activities to be conducted. The program also complies with the ESE Analytical Laboratory Safety Plan.

7.1 STANDARD PROCEDURES

7.1.1 WASTE CHARACTERISTICS

In the 43 year history of RMA, many extremely hazardous chemicals were manufactured, stored, or partially destroyed in demilitarization activities. Key compounds include GB and other nerve agents, H and L blister agents, munitions, organophosphorus pesticides and herbicides, phosgene, hydrazine, heavy metals, and chlorinated and unchlorinated organic solvents. High levels of organics have been detected in ground water in the area where Task 36 is concentrated. It is likely that some of these compounds may be encountered during the sampling and drilling activities to be carried out under Task 36. Detailed information on the chemical agents is given in the Agent Fact Sheet, SMCRM Form 357 (RMA, 1984) and Military Chemistry and Chemical Agents, TM 3-215 and AFM 355-7 (Departments of Army and Air Force, 1983). Copies of this information will be available at the Support Trailer at RMA.

7.1.2 GENERAL PROCEDURES

Task 36 activities include deep and shallow borings, well installation and development, and water sampling inside and outside RMA boundaries. These activities could expose field personnel to contaminated soils, rocks, and ground water. Because of this hazard, specific safety procedures are outlined later in this section. Communication requirements and buddy system procedures will remain the same as those detailed in the Task 1 (ESE, 1985, RIC#85127R07) and Task 4 (ESE, 1986a, RIC#86238R08) Technical Plans.

7.1.3 DRILLING OPERATIONS

Soil borings and well installation will involve both auger and water rotary and core drilling techniques. General procedures to be followed when working on the drill rig are as follows:

- Daily inspection of all ropes, cables, bolts, and moving parts of the rig is mandatory;
- Hard hats will be worn at all times in the vicinity of the drilling rig;
- Goggles or safety glasses will be worn when operating power tools, sanding, grinding, or filing. Welders glasses or a mask will be worn in the vicinity of welding operations;
- No loose fitting clothing or free long hair is permitted near the rig;
- Hands will be kept out of the way of moving parts of the machinery when drilling is in progress;
- A first-aid kit and fire extinguisher will be available at all times;
- All crews will consist of at least two persons;
- There will be no smoking, eating, or drinking, except in the base administrative area or the support trailers. In no case will smoking materials or matches be disposed of onsite; and
- No drilling will occur during impending electrical storms or when rain or icing conditions create a hazard in working with equipment.

Because of the different hazards involved with each type of drilling, technique-specific safety procedures will be followed. The following sections describe the different procedures.

Auger and Water Rotary Drilling

Auger drilling will be used whenever possible due to the fact that material from the hole is easier to collect and contain, and remains at ground level. Well installation and deep borings for Task 36 will take place in areas where the soil has been found to be largely uncontaminated. Ground water, however, in much of this area is contaminated. Level D protection with steel toe and shank boots may be worn until drilling reaches a depth of 20 ft above the estimated water table depth. At this time, field personnel will don the following protective clothing and equipment:

- Saranex coated coveralls;
- Hard hat with face shield;
- Steel toe, steel shank boots;
- Latex rubber boot covers;
- Two pairs of chemical resistent gloves;
- Full-face, air purifying respirator with Scott 642-OV-H chemical cartridges (readily available);
- Fifteen-minute escape pack (readily available); and
- Safety glasses when face shield is not needed to protect the eyes.

The Site Geologist has responsibility for air monitoring and general safety during drilling. Monitoring, using the HNU or TIP photoionization detector, will take place at least every 5 ft of drilling until water is encountered. Once water is encountered, monitoring will be continuous until the total depth of the hole is reached.

When concentrations of organic vapors reach levels from above background to 5 parts per million (ppm) in the breathing zone, full face air purifying respirators will be worn. Field crew members will be required to don Level B protection where vapor levels are 5 ppm to 500 ppm in the breathing zone.

Air Rotary Drilling

Air rotary drilling techniques may be used where auger or water rotary drilling is not appropriate. Air rotary ejects soil, mud, and water from the hole with great force. Because of the much greater possibility of contacting contaminated materials during air rotary, safety procedures will differ from auger drilling. The following equipment will be worn as full Level C protection:

- Hooded Saranex coated overall;
- Full face, air purifying respirator;
- Hard hat;
- Steel toe, steel shank rubber boots;
- Latex rubber boot covers;
- Chemical resistant gloves; and
- Fifteen minute escape pack.

Air monitoring will be extremely difficult because both the HNU and the TIP can become damaged when wet. There is also a danger of aspirating water or mud into the unit. While water and soil is being ejected from the borehole, no monitoring will take place in order to protect the instrument. During this time, full Level C protection will be worn. Also, in addition to the Saranex suit, drilling personnel will be required to wear a butyl rubber jacket over the Saranex suit to help repel the water. Other personnel working in the vicinity of the rig will be evaluated as to whether they will need a rubber jacket. These procedures will be followed whenever downhole material is being ejected from the boring.

Well Development, Water Sampling, Aquifer Testing, and Downhole Geophysical Logging

The greatest hazards from well development, well sampling, aquifer tests, and geophysics will be through skin contact with contaminated ground water and inhalation of volatile compounds being stripped from the water as it is being purged from the well. Field team members will don full Level C protection when approaching a well and removing its cap. The crew will then

monitor the breathing zone and downhole to determine the airborne hazards. Guidelines described for auger drilling will also apply to further respiratory protection.

When respirators are not worn, full face shields will be worn to protect the face from being splashed with contaminated water. Air monitoring will take place when each well casing volume is removed from the well or during pumping for aquifer tests. Detailed procedures for ground water sampling can be found in Section 7.0 of the Task 4 Technical Plan (ESE, 1986a, RIC#86238R08).

7.1.4 HOTLINES

Hotlines will be established in a circular fashion around each deep boring and well. For auger and water rotary drilling, well development, and sampling, the hotline will be a 30-ft radius around the well. Air rotary drilling activities will require a 50-ft-radius hotline around the well. The required personal protection will be worn by all individuals within these hotlines.

If deep borings and well installation requires both auger and air rotary drilling, the hotline can be modified as drilling progresses but only in an increased fashion. In other words, if the hotline starts out at a 30-ft radius, it can be enlarged to 50 ft when air rotary drilling begins. However, a hotline cannot be made smaller on the same well. Once the hotline is 50 ft, it will remain that way for the remainder of the boring or well installation. The Site Geologist will have the responsibility of establishing and enforcing the hotline.

7.1.5 DECONTAMINATION PROCEDURES

Decontamination procedures will follow those procedures outlined in the Task 4 Technical Plan, Section 7.0. In summary these procedures are as follows:

- Vehicle seats and floorboards will be covered with plastic to aid in keeping them clean;

- All vehicles, equipment, and personnel entering the hot area will require decontamination;
- An initial decontamination will take place at the well site; and
- Field personnel will remove plastic from the inside of vehicles and proceed to the field wash trailer for showers.

7.2 CONTINGENCY PLANS

7.2.1 CHEMICAL AGENTS AND ORDNANCE

It is highly unlikely that chemical agents or ordnance will be encountered in the Task 36 study area. However, all crews will be supplied with M-8 detector paper as a precaution. The Site Geologists will be required to test formation water with this paper to check for agents in the water.

If chemical agent is detected, the emergency and evacuation procedures posted in the Command Post and field wash trailers, and detailed in the Task 1 Technical Plan (ESE, 1985, RIC#85127R07) will be followed.

7.2.2 EMERGENCY PROCEDURES AND SERVICES

In the event of an emergency onpost, (i.e., serious injury, fire, agent detection), the first point of contact will be the RMA Fire Department. For more detailed procedures for emergency situations refer to the Task 1 Technical Plan (ESE, 1985, RIC#85127R07). In the event of an offpost emergency, the first point of contact will be the Brighton Fire Department for the area north of 96th Avenue and east of Highway 2, and the Commerce City Fire Department for the area northwest of RMA.

8.0 SYSTEM ASSESSMENT/REMEDIAL ACTION

The objective of the response action assessment of the system components and geologic and hydrologic conditions is to determine the adequacy of the control system to intercept ground water contamination migrating in both the alluvial and Denver aquifers near the North Boundary. This response action assessment has been broken into three major areas of study to determine how much each may contribute to control system problems. The three components to be assessed are: the operation of the existing dewatering/recharge components, the flow of ground water that is by-passing the system, and the physical condition of the bentonite slurry wall. The results of this integrated study will be used to make corrective recommendations to improve the system.

All assessment components will be investigated in close consultation with personnel from PMO-RMA, NBCS Operations, and Waterways Experiment Station (WES) while evaluating existing data, collecting new data, and evaluating response action alternatives. ESE will incorporate information obtained from the data review with data generated through the field programs to update the background information appendix of the Technical Plan. This shall be included as a separate appendix of the Technical Plan. The Technical Report shall be prepared, discussing all technical work performed and assessments made, as described in and in accordance with DD Form 1423, A011. As a minimum, ESE will conduct monthly working sessions or Progress/Status Meetings with the PMO-RMA staff. ESE will present an oral briefing of drafts of the Technical Reports for the NBCS at Rocky Mountain Arsenal, Commerce City, Colorado.

8.1 ASSESSMENT OF DEWATERING AND RECHARGE COMPONENTS

More than any other factor, the inability of the NBCS to handle required flow rates at certain times has led to increased potential for flow of ground water through and around the control system. The objective of this portion of the study is to analyze the different components of the system, address operational and design problems associated with each, and develop conceptual solutions that can be implemented into cost-effective system alterations.

8.1.1 DEWATERING SYSTEM

It is evident from recent studies (Thompson, et al., 1985) that the treatment system flow has not consistently reflected the total flow of ground water approaching the barrier. Instead, the flow through the system reflects its ability to pump, treat, and recharge water at a rate that is often less than total ground water flow and is attributed most often to the lack of recharge capacity of the system.

The dewatering system may be responsible for part of the system's inability to handle required flows. Generally, the problems encountered with dewatering fall into two categories. First, the system has had mechanical problems which are due primarily to adverse weather conditions such as freezing and lightning strikes. Secondly, some of the dewatering wells are located in an unsuitable geologic environment. This includes wells which were placed in partially cemented gravelly sands and clay or clayey sand which have diminished dewatering capability.

The assessment of the dewatering system will focus on methods of improving reliability, means of rehabilitating wells that have performed poorly and adding wells or other dewatering units. The goal of the assessment and subsequent recommendations will be to ensure that the modified system can reliably intercept all contaminated ground water approaching the North Boundary. Proper distribution and geologic placement of new dewatering units will be crucial to enhancing the existing system's capability and reliability.

To achieve the goals of the study, an accurate depiction of the hydrogeologic media upgradient of the barrier is required. In this respect, existing data will be supplemented by ongoing programs to define problem areas and provide indications of suitable locations for new dewatering units. Inspection of existing well logs and testing of the dewatering system currently installed, will provide additional data useful for design and placement of additional dewatering wells or alternatives.

The assessment of dewatering capability will also address modifications that will enhance the reliability of the system. This aspect of the study will emphasize mechanical problems that have been identified in the past and are likely to occur again based on historic trends. Conceptual design modifications, additional maintenance needs, and/or operational changes will be identified to improve efficiency and minimize down time.

8.1.2 RECHARGE SYSTEM

Several problems have been identified in the operation of the recharge system. The most notable of the problems is the insufficient number of recharge wells that appear to be necessary to recharge the water. Mechanical problems resulting from freezing and lightning strikes have also affected the recharge system. Even more important, the recharge system lacks sufficient recharge capability because of wells that were screened in areas of low permeability. In addition, carbon fines from the adsorbers in the treatment system have migrated through the post-filter to the recharge wells and further decreased recharge capability.

The assessment and recommendations for the recharge system will focus on means of maximizing existing recharge capabilities by implementation of additional maintenance programs, treatment system modifications to minimize the amount of carbon fines being discharged and addition of new wells or other recharge alternatives to increase total recharge capability.

Evaluation of the siting of new recharge units will focus on placing the units in suitable geologic locations and minimizing effects on the regional ground water flow. Conceptual design of wells and other system components will specifically address those problems that have been identified in the past or are likely to occur based on historic trends and engineering judgement.

Modifications to the recharge system will ensure that it has the capability to recharge 125 percent of dewatering flows while accounting for expected downtime and deterioration of wells. This margin of safety will provide for

adequate recharge even during unexpected mechanical failures and/or periods when recharge units are not functioning at design levels.

Site investigations to be performed under this task will be utilized along with existing data to define a comprehensive view of the geology in the existing and proposed recharge areas. Assimilation of data will include inspection of existing well logs, evaluation of well performance records, and performance of pumping tests on existing wells. Analytical methods will subsequently be employed to find the optimal design, siting, and arrangement of additional recharge wells or other alternatives. The conceptual design will be optimized to handle design flows while minimizing effects to the regional ground water flow.

8.2 ASSESSMENT OF FLOW BY-PASSING SYSTEM

Regardless of the capability of the system components to fully handle all of the contaminated ground water flow encountered by the system, geohydrologic conditions appear to exist that allow flow around or under the barrier. These conditions may be exacerbated when hydrologic conditions are created during system shutdown or at times when the system cannot keep pace with flow, so that these ground water flows could become contaminated and evade treatment by the system. The objective of this part of the assessment is to evaluate in detail the geologic and hydrologic conditions that are allowing or will allow contaminated ground water to by-pass the system. The results of this detailed hydrogeologic assessment will be used to suggest any cost effective design concept modifications along with operational modifications that may be implemented to improve system function and control these ground water flows.

8.2.1 FLOW AROUND SYSTEM

8.2.1.1 Geologic Investigations

The geologic and hydrologic conditions in the vicinity of the ends of the system will be compiled and compared to contaminant plumes in the alluvial and Denver aquifers to evaluate whether the lateral extent of the dewatering and slurry wall components of the NBCS are sufficient to capture all

contaminated flow. This investigation will utilize existing data and new data acquired by drilling and field investigations to compile detailed geologic cross sections and maps showing the configuration of alluvial and Denver Formation lithologies. Hydrologic and geochemical data will be compiled and then plotted onto the geologic interpretations and compared to system construction diagrams to see if the system is intercepting the full lateral extent of the plumes. This analysis would be used to assess various control options, such as the lateral expansion of alluvial and/or Denver aquifer dewatering wells if necessary to intercept the plumes.

8.2.2 FLOW IMMEDIATELY BELOW BARRIER WALL

The Thompson, et al. (1985) Performance Report outlined a suspected zone of contaminant migration below the pilot portion of the system. This analysis will detail that zone as well as further investigate areas beneath the expansion portion of the system to verify its integrity.

8.2.2.1 Geologic Investigations

A detailed analysis of the Denver Formation at the base of the wall will be performed using compilation of old and new lithologic data. This will include an assessment of the ability of the fractured shale to conduct flow. It may be necessary to drill some angled core holes into the Denver Formation to collect oriented core for fracture analysis because vertical holes would not be likely to intersect vertical or high angle fractures. Vertical fractures are the type most likely to cause vertical and lateral flow. Data will be presented as geologic cross sections and maps showing lithology as well as structural data such as fracture orientation and density.

8.2.2.2 In Situ Tests

Hydrologic data will be needed on the Denver Formation at the base of the barrier wall. May et al. (1980) have pointed out that field and laboratory tests have shown the fractured shale locally has permeabilities caused by fracture and joint interconnectivity comparable to the Denver Formation sandstones. Additional pump tests on wells completed in the shale zone

below the wall will give data on local values of permeability. In addition, lab permeability tests run on samples collected from the core drilling will give pertinent information.

8.2.2.3 Analysis

Hydrologic, chemical, and geologic data will be plotted together with system construction details to give a three-dimensional analysis of the capability of the bedrock at the base of the wall to conduct or impede ground water flow. Ground water flow rates will be estimated for this part of the system. Analysis of the fractured shale will include an assessment of whether to include this zone in the control component of the system so as to intercept any significant flow that occurs in it.

8.2.3 DEEP FLOW BELOW BARRIER WALL

Historic detection of contamination in Denver Formation wells as well as recent documentation of offpost contamination in areas where Denver sandstones are projected to subcrop (ESE, 1986b) dictates that substantial effort should be given to determining the three dimensional configuration of the sandstone bodies and their effect on the ground water hydrology. This analysis will overlap with the Task 39 program offpost and the Tasks 25 and 4 (future Task 44) programs onpost. Some part of this assessment will investigate whether the source of contamination in deeper Denver sandstones near the North Boundary is a result of local infiltration near the NBCS (possibly caused by the operation of the system itself) or whether contamination has migrated from a source upgradient. Access of contaminants to the deeper sandstones could be by natural pathways (i.e., contact between sandstones and contaminated alluvial flow or through fractured shale) or from man induced features.

8.2.3.1 Geologic Investigations

Geological data will be compiled onto cross sections and maps to determine the lateral continuity and extent of the Denver sandstones. This will include geologic data from existing and new monitor wells and boreholes and domestic wells offpost. Hydrologic and chemical data will be plotted onto

these geologic bases to determine the total influence the Denver Formation has on contaminant transport in the area. This analysis will focus on determining the entry point(s) for contamination into these units (local vs. upgradient).

8.2.3.2 In Situ Tests

To fully characterize the hydrology of the Denver Formation sandstones, additional aquifer tests may be required. Pump tests and/or slug tests will be conducted where appropriate. A series of pump tests are proposed offpost in Task 39 to give data for the modeling program. Where that data is useful in this study, especially in the vicinity of the suspected discharge area of the Denver sandstones into the alluvium, it will be utilized.

8.2.3.3 Leaking Wells

Thompson, et al, (1985) documented poor well construction for dewatering well 23342. At best, the poor construction gives a false detection of contamination in a deep Denver sandstone and at worst it could be a significant source for infiltration of pollutants from contaminated shallow sandstones into deeper units. Other existing wells will be evaluated for construction flaws and appropriate response actions will be recommended.

8.3 BARRIER WALL ASSESSMENT

The initial function of the subsurface barrier at the North Boundary was twofold. First, the barrier was to assist in reducing the ground water flow in the system by increasing the drawdown on the upstream side and increasing the mounding effect on the downgradient side by preventing the recirculation of treated ground water. The original design intended that there would be no head difference across the wall. In this respect, the wall was to act as a divider between contaminated water approaching the upgradient side and the treated water on the downgradient side.

The second function of the trench was to act as a temporary "ground water dam" during downtime of the dewatering and/or recharge system. Due to the mechanical failure of some of the dewatering and recharge wells and the

unsuitable geologic placement of certain recharge wells, the soil-bentonite barrier has consistently had to act as a ground water dam. This fact is significant for two major reasons as far as the integrity of the barrier itself is concerned. First, larger head differences across the wall caused by the "damming" effect would increase flow through the barrier. This would accentuate any existing zones of higher permeability within the wall. Secondly, the potential for exposure of the wall to possibly degrading contaminants is increased with larger head differences and thus greater flows. The extended period of the present "damming" condition implies that contaminant-barrier contact is more likely than previously surmised based on original design intentions.

Further contaminant contact with the barrier and hence, potential flow through the barrier, could be minimized by eliminating the head difference across the wall. Reducing this head difference will be the primary emphasis of this study. However, the efficiency of the wall in retarding flow remains important when considering the reduction of recirculation and the unexpected downtime of the hydraulic system when the barrier could still be required to act as a ground water dam.

8.3.1 IDENTIFICATION OF GENERAL PROBLEMS

Analysis of the barrier will focus on identifying factors which could lead to substantially increased hydraulic conductivity. Several physical factors must be considered when evaluating the long term integrity and effectiveness of soil-bentonite trenches when used to control pollution migration.

Physical factors that may influence trench effectiveness include the subsurface conditions surrounding the wall, the characteristics of the soil-bentonite mixture and the quality and quantity of filter cake formed along the trench walls. Examples of subsurface considerations that should be examined include the hydraulic gradient across the wall, in situ stresses and ground movement.

The characteristics of the soil-bentonite trench will be dependent upon the type and relative quantity of bentonite and backfill, the quality of mixing and backfilling operations and the effects of any contaminants. Effects from contaminants could be from utilizing contaminated water and/or backfill in the initial construction or subsequent effects from contaminated ground water.

8.3.2 IDENTIFICATION OF SPECIFIC PROBLEMS

An extensive review of data related to the NBCS will be undertaken to focus investigative efforts on those factors that pose potential problems. This review will include a detailed analysis of the barrier design and construction, an investigation of contaminants that may have come into contact with the soil-bentonite mixture and an evaluation of the hydrogeologic media surrounding the wall.

This initial review will recognize the difference in design, construction, and extent of exposure to contaminants between the pilot barrier and the extension. This differentiation is important in evaluating the applicability of various proposed investigations. For example, an investigation to determine the effect of certain contaminants might be applicable to the pilot barrier section but not the extension based on the historic location and movement of a contaminant and the differences in the age, construction methods, and consistency of the two barriers.

Analysis of the design and construction of the barrier will help to pinpoint potential problem areas within the wall. This analysis will include assessment of the soil-bentonite composition of the wall, general construction procedures and problems that were identified during installation. This encompasses documentation of any tests that were performed at the time of construction and inspections of the finished wall.

A review of contaminants that may have been and are presently near the barrier will be performed. Estimates of concentrations and length of exposure will be determined. Emphasis will be on contaminants that have

caused or are suspected of causing detrimental effects to soil-bentonite mixtures. Determination of which, if any, detrimental contaminants exist in the vicinity of the barrier will dictate the types and extent of tests to be performed.

A detailed evaluation of subsurface conditions surrounding the wall will provide valuable data on the effectiveness of the barrier. This investigation could help define areas of higher permeability and thus zones with greater potential for contaminant transport. The analysis will focus on historic and current water-levels on either side of the trench and the location and concentration of contaminants on the downgradient side.

8.3.3 MONITORING AND TESTING PROGRAM

8.3.3.1 Monitoring

Accurate water level data around the wall will be an integral part of determining zones of excessive flow through or around the barrier. Existing data should be supplemented by measuring water levels or pore pressures on both sides of the wall where existing wells are sparse.

Several methods are available to determine water levels. An open standpipe (or well point) is the simplest option but is generally considered a permanent installation. More temporary measures may be more appropriate due to the short-term nature of this assessment. However, the installation of a network of data points of high density will allow future detailed evaluations of the system, especially to monitor the effectiveness of remedial modifications that will be implemented from this study.

Evaluation of the contaminants downgradient of the barrier will provide invaluable information on the integrity of the wall. Historic location and concentrations of contaminants will be used to help pinpoint potential areas of concern. These efforts have been ongoing and should be augmented substantially by proposed new monitoring sites.

8.3.3.2 Testing

Based on review of construction records, historic contaminant plumes, and water level data, a testing program will be implemented to investigate zones of questionable integrity. Several testing options will be evaluated for their applicability to problems that are identified.

This first option consists of sampling the barrier and analyzing samples to determine permeability and whether the samples have undergone adverse physical changes due to contaminant interactions or adverse subsurface conditions. Permeability determinations will be made using laboratory tests performed at low gradients. In addition, X-ray diffraction and/or chemical analysis could be used to identify the percentage, composition, and crystallographic structure of bentonite. Grain size distribution tests can be used to document the amount of fines. Possible adverse chemical-soil-bentonite interactions that should be evaluated include dissolution, shrinkage, and flocculation.

Every effort will be taken to minimize the number of samples withdrawn from the wall due to the obvious disturbance and reduction in integrity that would result. Holes created by sampling operations will be grouted or filled with a compatible soil-bentonite mixture immediately afterward to minimize increased flow in these areas.

Several in situ tests may be of value in assessing the condition of the barrier. One option is the utilization of cone penetrometer tests to determine large nonhomogeneous zones within the trench. This determination could be made by comparing tip resistance and sleeve friction values at different depths within the trench. It is postulated that large zones of caving or poorly mixed backfill might be evident by substantially different resistance values. It is also probable that zones of coarse material might be evident by more rapid dissipation of excess pore pressure dissipation if pore pressures are monitored. This investigation would focus on areas suspected of higher permeability based on monitoring and other preliminary investigations.

Cone penetrometer tests should result in minimal withdrawal of material from the barrier; however, such tests will increase pore pressures within the trench and could leave holes within the wall. These drawbacks and the lack of data that would be obtained indiate that sampling the barrier is a more appropriate method of investigation.

In situ slug type permeability tests are not recommended for this study due to the increased hydraulic pressures created. These tests have been known to cause hydraulic fracturing in fine-grained soils and may give erroneous values for low permeability materials.

A full scale test could be utilized to determine the effective permeability of the barrier and the media surrounding the barrier. This would be conducted by monitoring the rate at which the hydraulic gradient across the wall changes during downtime of the dewatering/recharge system. The effective permeability could then be calculated using a falling head type analysis. This would be only approximate, however, because of the complexity of site conditions and the fact that the analysis is generally more suited to relatively permeable soils. The option will not be undertaken during this task because it might involve adversely altering system operation.

8.4 ASSESSMENT OF OVERALL SYSTEM INTEGRITY

The results of all of the individual system component assessments will be integrated and apportioned as to how each contributes to the control problems of the system to fully handle contaminated ground water flow in the area. In addition, an analysis of the interdependence of the components will be done so that the response actions that are recommended will be technically sound and cost effective. For example, if it is determined that deep sandstones are conducting contaminants offpost, and that the sources of the contaminants into the sandstones are leaking wells, then by removing the leaking wells, the contribution of the deep Denver sandstones to the by-pass of the system will be negated. It would undoubtably be more logical to

remediate leaking wells than to commit to building additional deep dewatering capacity and operating it for a long period of time to solve this hypothetical problem.

8.5 RECOMMENDATIONS

A detailed discussion of recommendations for improvement to the NBCS will be presented that takes into account the overall system integrity results discussed in Section 8.4. The recommendations will be categorized as to whether they should be considered for implementation as interim actions or will be evaluated as final response actions in the overall feasibility study. Recommendations for an interim action will be based upon the need to improve system operation before a final response action can be implemented.

9.0 MANAGEMENT AND ADMINISTRATION

ESE will devote sufficient project management, planning, consultant, supervisory, administrative, and clerical staff to ensure maintenance of a smoothly operating program, without impact on previous, ongoing, or subsequent tasks. A Management Plan has been prepared in accordance with DD Form 1423, A003, that includes a Resource Utilization Plan for this task, and Cost and Performance Reporting consistent with requirements of Task 1 (ESE, 1985, RIC#85127R07). Computer-to-computer communications will be maintained as implemented in Task 1 (ESE, 1985, RIC#85127R07). All simultaneous tasks that have overlapping technical, geographic, and management needs will be coordinated to achieve maximum efficiency and output.

10.0 ADDENDUMS

This section is left intentionally blank for future Task 36 revisions.

February 13, 1987
Revised February 24, 1987
Project No. 86958

Letter Technical Plan

Re: Task 36, Rocky Mountain Arsenal North Boundary System Component Remedial Action Assessment; Soil-Bentonite Barrier Assessment

As outlined in the Draft Technical Plan and the Letter Technical Plan of January 2, 1987, Environmental Science and Engineering, Inc. (ESE) has recommended that existing alluvial water level monitoring wells be supplemented with additional open standpipes to adequately describe hydraulic conditions on both sides of the soil-bentonite barrier. There are two primary reasons for these installations. First, these monitoring points will provide invaluable data on the present effectiveness of the dewatering and recharge systems and their operations. Additional water level data will help further delineate problem areas and will be used in the conceptual design of additions and/or modifications to the present dewatering/recharge system. The proposed system will also provide reliable documentation of the effectiveness of proposed changes to correct adverse hydraulic conditions. The second reason for the system is to help delineate zones of questionable integrity within the soil-bentonite barrier. Specific areas to be sampled within the barrier will be guided by data obtained from the proposed water level measuring system.

The following is a list of existing wells that are close enough to the barrier and adequately constructed to give reliable measurements of water table elevations around the barrier:

23205	24178
23208	24179
23146	24180
24173	24181
24176	24182
24177	24183

It appears that all of these wells, except for 24176, are presently being monitored for water levels. These wells provide a substantial amount of information around the extension portion of the barrier. However, the areas of high contamination upgradient of the pilot barrier are not covered by existing wells. The proposed system has therefore been outlined to address the area around the pilot barrier. The approximate location and number of proposed sites are shown on the enclosed map along with the existing wells that will be utilized. The exact location and number of standpipes may be adjusted in the field to avoid construction difficulties and to provide data where it is most needed. Wells will be located as close to the barrier (approximately 25 feet) as feasible so that water level data will accurately reflect the hydrologic conditions immediately upgradient and downgradient of the barrier.

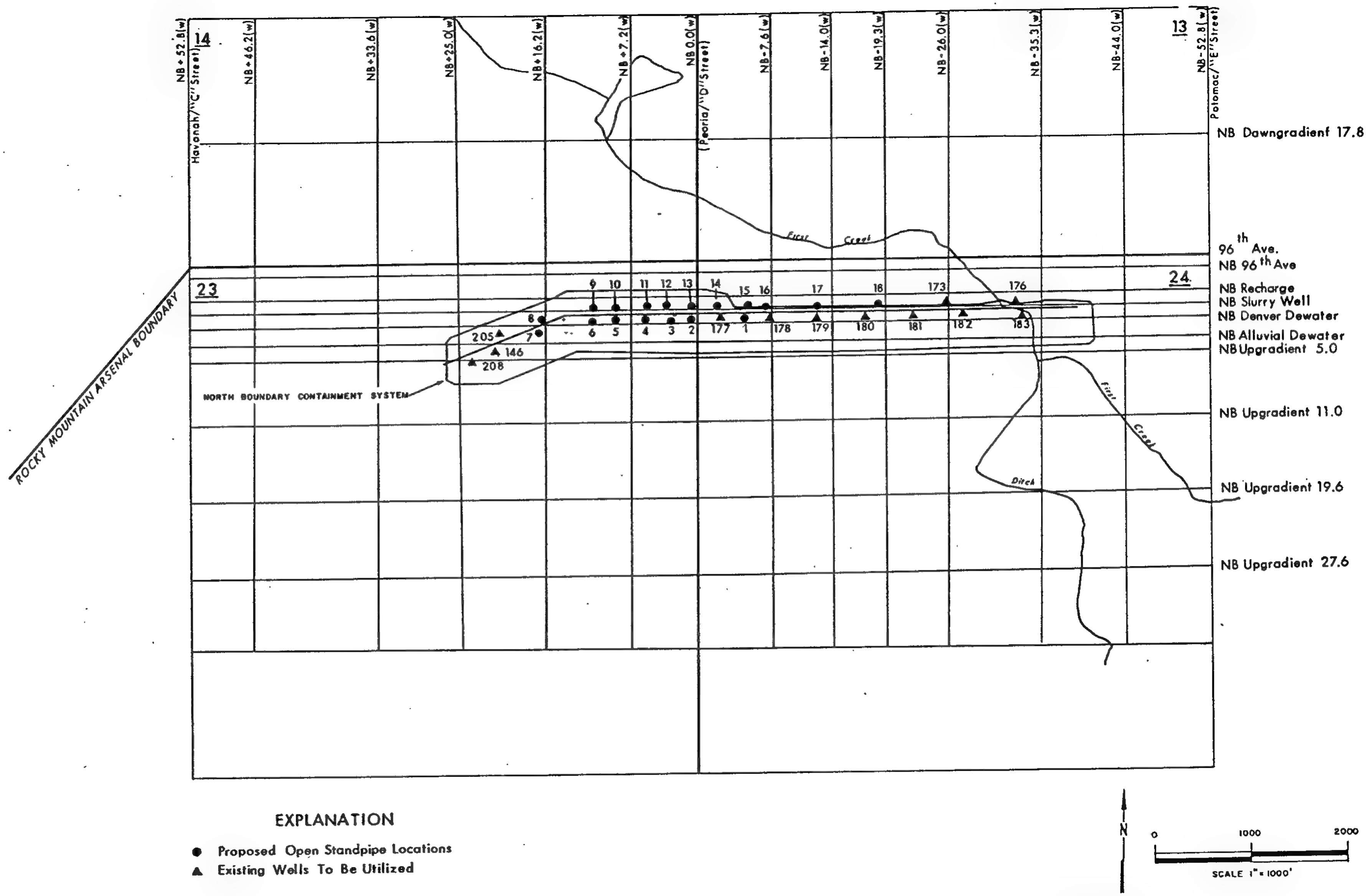
It is recommended that stainless steel pipe be driven where possible to minimize costs. However, where this is not feasible, sites will be drilled using hollow-stem augers or direct rotary methods. In this case, 1-inch (in) or 2-in (ID) 20 slot (0.020-in) PVC will be used as well screen. For all standpipes, the screened interval will be placed so that seasonal variations are taken into account along with possible water table changes from probable dewatering/recharge modifications.

For all wells, either blank PVC or stainless steel pipe casing will extend from the screened interval to 2 ft above the ground surface. 4-in-diameter steel pipe will be set into a 3 ft deep grout seal surrounding the well for protection. PVC caps will be used to seal the top of all wells. It is recommended that approximately three downgradient sites in the area of the pilot barrier be sampled using direct rotary or hollow-stem auger sampling techniques. These samples would be logged at a central logging facility. This data would be used to define the geology immediately downgradient of the barrier and would be used to help evaluate recharge additions that may be proposed under this task.

Prepared by,

Mark E. McClain

Mark E. McClain, P.E.
Task Manager



EXPLANATION

● Proposed Open Standpipe Locations
▲ Existing Wells To Be Utilized

PROPOSED SYSTEM OF WATER LEVEL MONITORING POINTS AT NORTH BOUNDARY

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

January 02, 1987
Revised February 23, 1987.
Project No. 86958

Letter Technical Plan

Re: Task 36, Rocky Mountain Arsenal North Boundary System Component Remedial Action Assessment; Soil-Bentonite Barrier Assessment

Pursuant to the objectives identified for the Rocky Mountain Arsenal (RMA) North Boundary System Component Remedial Action Assessment, Environmental Science and Engineering, Inc. (ESE) has outlined a proposed program to assess the physical condition of the soil-bentonite barrier. The investigative program is designed to concentrate on areas within the barrier suspected of deterioration and/or relatively high permeability while minimizing overall disturbance. The rationale and details of the plan are described in this report. It is noted that the emphasis of this task will be placed on reducing hydaulic gradients across the wall which is the most effective means of minimizing flow through it.

The investigative program is developed to detect specific problems that may have occurred due to poor construction and/or adverse physical and chemical conditions. A brief review of the phenomena which may have adversely affected the integrity of the barrier and the likelihood of their occurrence, are briefly discussed below:

- Piping - Piping can be caused by excessive hydraulic gradients in conjunction with the use of improper backfill materials or construction procedures. Piping failures can be avoided by utilizing proper construction procedures, choosing suitable backfill materials and keeping hydraulic gradients across the barrier within design levels. The most important parameter for the backfill materials is the amount of fines (percent passing #200 sieve). Generally, a fines content of 20 to 25 percent is adequate to resist gradients of from 10 to 20 across the wall. The gradients at the North Boundary (NB) have reached a maximum of approximately 4. Therefore, if the required amount of fines were mixed in the original backfill and proper construction procedures used, piping should not be a concern for the barrier. A fines content of over 50 percent has been documented for the NB extension barrier. Documentation of the fines content for the pilot barrier has not been obtained by ESE. This information should be obtained from the investigative program if it can not be documented from other sources.

- Windows - "Windowing" in the barrier could occur by the placing of large quantities of unblended backfill or by sloughing of portions of the trench sides during excavation. Based on review of available construction records (U.S. Army Corps of Engineers, 1984) and conversations with RMA personnel, it appears that the original pilot and extension barriers were constructed from backfill materials that were adequately mixed with slurry before placement.

Based on this information and conversations with consultants involved with the barrier construction (Shallard, 1986), it does not appear likely that large and numerous zones of unblended material would exist within the barrier.

- Slurry Pockets - Slurry pockets can be formed during construction of soil-bentonite barriers if the slump of the backfill material is to great. This is caused when the backfill folds over itself and entraps the slurry. These pockets can remain in the wall and act like compressible layers with lower resistance to hydraulic gradients and chemical attack than the surrounding backfill (EPA, 1984). Based on construction records (U.S. Army Corps of Engineers, 1984) and conversations with consultants (Shallard, 1986), it seems that adequate measures were employed to minimize the possibility of entrapped slurry existing in the completed barrier.

- Chemical Effects - Ground water contaminants can substantially affect the physical/chemical properties of the bentonite and backfill material comprising the barrier (EPA, 1984). These interactions can lead to increased permeability of the barrier and in a worst case, piping or tunnelling failure of the wall. Numerous organic and inorganic contaminants can, through a variety of mechanisms, cause bentonite clay particles to shrink or swell. All of these mechanisms affect the quantity of water contained within the interspatial layers of the clay structure. In particular, inorganic salts can reduce the double layer of partially bound water surrounding the hydrated bentonite, thus reducing the effective size of the clay particles (D'Appolonia and Ryan, 1979). Organic contaminants can be sorbed into the internal surfaces of clay particles thus affecting the interlayer spacings (Anderson and Brown, 1981). These effects can lead to substantial increases in the permeability of the wall by increasing the amount of pore space in the backfill.

Of particular concern at the NB, are the high levels of calcium which have been found in the ground water near the barrier. Concentrations of calcium in excess of 800 ppm have been measured in this area. Prolonged exposure to ground water containing these high-levels of calcium may cause shrinkage and flocculation of the clay particles. These effects should be considered when determining what type of investigative program to employ.

In order to effectively evaluate the critical areas of the barrier, it is recommended that the investigations be directed by a thorough review of the construction history of the barrier and the contaminant concentrations and water levels around the barrier. In particular, the investigation should focus on determining whether the problems described above exist while minimizing disturbance to the barrier.

To achieve these goals it is recommended that additional water level monitoring points be installed on both sides of the barrier. For this purpose, well points could be installed at regular intervals and would

provide an accurate depiction of the hydraulic gradient across the wall. This information would be extremely beneficial in identifying zones of higher permeability within the wall, would not disturb the integrity of the barrier and would provide indications of the effectiveness of any modifications to the dewatering/recharge systems.

Utilizing water level and contaminant distribution data from around the barrier, a program of investigation will be initiated to assess the barrier's integrity in areas that are considered suspect. Two investigative techniques have been considered. The first is the electric cone penetrometer test (CPT). The CPT has been used effectively in recent years to classify subsurface materials based on measurements of cone bearing resistance, friction ratio and most recently, pore pressure. It is an attractive alternative for examining the condition of the barrier because of the minimal disturbance that it would cause.

The primary use of the CPT would be to delineate large zones of coarse material ("windows") within the wall. It is probable that the resistance values from the CPT could be read accurately enough to detect coarse grain zones less than a foot thick (Carter, R., 1986). However, based on review of the construction procedures, it appears that the mixing of backfill material and slurry was adequate to prevent the widespread occurrence of large unmixed zones.

Field studies performed by the U.S. Bureau of Reclamation (Engemoen, W. and Hensley, P., 1985) have been conducted to determine the effectiveness of the CPT in identifying slurry pockets. The results of these investigations showed that the CPT did not provide any reliable indications as to whether slurry pockets existed in the barrier studied. It is thus concluded that the CPT would be of limited use during the present investigation.

An alternative to the CPT is the withdrawal of samples from suspect zones for inspection and testing. The primary advantage of this technique is that it could be used to evaluate any effects from soil-bentonite and contaminant interactions and the other phenomena described above. Disturbance to the barrier can be minimized by immediate filling with compatible grouting materials.

Based on the data presented above, it is our opinion that sampling the barrier will be a more effective method of examining its integrity than performing cone penetration tests. The proposed sampling would be restricted to zones of questionable integrity as delineated by contaminant concentrations and water level data.

Permeability tests are recommended for selected samples to document representative hydraulic conductivity values for the barrier. X-ray diffraction tests are proposed for samples withdrawn from high contamination areas to assess any changes that may have occurred due to soil-bentonite and

contaminant interactions. All samples will be visually inspected for any abnormalities. Grain size distributions should be determined for the pilot barrier to document the percentage of fine-grained materials.

ESE proposes that this program would provide a representative and reliable indication of the condition of the soil-bentonite barrier.

Prepared by,

Mark E. McClain

Mark E. McClain, P.E.
Senior Associate Engineer

BIBLIOGRAPHY

Anderson, D. and K.W. Brown. 1981. Organic Leachate Effects on the Permeability of Clay Liners, in Land Disposal of Hazardous Waste. Publication No. EPA-600/9-81-002. U.S. Environmental Protection Agency, Municipal Environmental Research Laboratory, Cincinnati, Ohio.

Carter, R. 1986. Civil Engineer, Bureau of Reclamation. Conversation-November, 1986.

D'Appolonia, D.J. and C. Ryan. 1979. Soil-Bentonite Slurry Trench Cut-off Walls. Engineered Construction International, Inc. Presented at the Geotechnical Exhibition and Technical Conference, Chicago, Illinois.

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Shallard, G. 1986. Geotechnicial Engineer. International Technology Corporation. Conversation-October, 1986.

U.S. Army Corps of Engineers. 1984. Final Construction Foundation Report, North Boundary Expansion Containment System. Rocky Mountain Arsenal, Commerce City, Colorado.

November 26, 1986
Project No. 86946

Letter Technical Plan

Re: Tasks 25, 36, and 39-Offpost Monitoring Well Installation Program

Enclosed is information concerning Task 39, Offpost Remedial Investigation/Feasibility Study (RI/FS) at Rocky Mountain Arsenal (RMA). Environmental Science and Engineering, Inc. (ESE) has defined the objectives for the offpost monitoring well installation program and has prepared a tentative drilling sequence. Monitoring well locations are shown on the map which accompanied our August 14, 1986 Letter Technical Plan.

Also enclosed is a description of how the wells will be completed including various conditions for which conductive casing will be used to protect against cross-contamination between aquifers.

DRILLING PROGRAM OBJECTIVES AND TENTATIVE SEQUENCING

ESE has defined the objectives and estimated the drilling sequence for installation of offpost alluvial and Denver Formation wells. The programs are as follows:

ALLUVIAL WELLS

- Objectives-Define pathway(s) for potential contaminant transport between the North Boundary of RMA and the 37344-Boller wells. It appears that alluvial ground water contaminated with RMA-specific compounds such as DIMP and DCPD is migrating north from RMA to the Boller well through the east half of Section 13. ESE will attempt to trace the plume southward from the 37344-Boller wells by installing alluvial monitor well(s) in the area of site E-53. Subsequently one or more monitor wells in the areas of E-45, E-46, E-47, and E-63 will be installed as appropriate;

  -Define the extent and concentration of alluvial ground water contamination downgradient of the Boller wells by installing one or more wells at or near site E-58;

  -Define extent of plume near the 37313 well by installing one or more wells in the area of E-50;

  -Establish or better define contaminant levels and pathways in alluvial ground water between the North Boundary of RMA and the area of well 37313. This will entail installation of alluvial wells at sites E-44, E-42, and E-39 as appropriate; and

  -Evaluate and define alluvial ground water contamination downgradient of the Northwest Boundary Containment System by installing one or more wells in the area of sites E-55 and E-60. The well siting would be based on water quality data from the Task 25 screening quarter and will be installed under Task 25.

o Tentative Sequencing-Wells will be installed at or near sites E-53 and E-58;
-Wells will be installed at or near sites E-39, E-42, and E-44;
-Newly installed wells will be sampled two weeks after completion and development;
-Based upon the results, additional wells may be installed near sites E-53 (E-54, E-64) and E-58 (E-52, E-57, E-59) and in the area of sites E-45 and E-47 (E-46);
-Based upon sample results from Task 25, one or more well will be installed near site E-63;
-Based upon sample results from Task 25, one or more wells will be installed near site E-55;
-Siting of some alluvial wells, particularly those in Section 13, will depend upon data from the soil/rock boring program; and
-The drilling sequence is highly variable, depending upon data evaluation from prior sampling, permits, and rights-of-way, and access.

DENVER FORMATION WELLS

o Objectives-Determine contaminant levels and pathways in certain sand horizons known to be contaminated upgradient of or peripheral to the North Boundary Containment System; and
-Evaluate contaminant levels in the upper part of the subcropping Denver Formation beneath areas of contaminated alluvium.

o Tentative Sequencing-Continuously cored borings will be drilled to determine the extent and geometry of Denver sand horizons that are contaminated onpost. The area of principal concern here extends from the North Boundary of RMA to First Creek. Bore holes at sites E-38, E-39, E-40, E-41, E-42, and E-63 will be drilled to depths of 100 to 150 feet (ft). An area of secondary concern for Denver Formation ground water contamination extends from north of First Creek to the area of the Boller wells. Cored borings in this area will be drilled to depths of 50 to 100 ft;
-When enough information is available from the boring program to outline the geology of the Denver Formation as it relates to contaminant transport, monitor wells will be installed in the key sand horizons that are contaminated onpost. At each site in the area between the North Boundary of RMA and First Creek, wells will most likely be installed in the upper two sand horizons of the Denver Formations. If, however, the second sand horizon on RMA is found by Task 25 sampling to be uncontaminated, then wells will only be installed

in the upper sand horizon;

- In the northern part of Sections 13 and 14, Denver wells will be installed only in the uppermost sand horizon below the first shale. These will be installed to evaluate the possibility of contaminant transport in Denver Formation sands;
- Surface geophysical techniques may be used to help site alluvial wells but only after general agreement as to efficiency of method and cost;
- Borehole geophysical techniques will be used to define stratigraphy in the Denver Formation. The logging suite will be chosen after discussion with EBASCO, R.L. Stollar and Associates, and Harding Lawson Associates; and
- The program will be dynamic and new data may require alteration to the plans. The alterations would be made only after discussion with PMO-RMA.

DENVER FORMATION WELL COMPLETION PROCEDURES

OBJECTIVES

The purpose of isolating overlying strata from sandstone aquifers in the Denver Formation north and northwest of RMA is to prevent introduction of overlying contamination and the downward migration of contamination during drilling and monitor well installation.

METHODS

Methods and materials will be on a well specific basis. Specific installation techniques are shown for the different conditions to be encountered as diagramed in the following attachments. Wells will be insulated from overlying strata with threaded conductor casing and cemented in place in accordance with accepted Halliburton guidelines. The conductor casing, centralizers, and all downhole materials will be steam cleaned before placement. Proper steps will be taken during mixing of and annular placement of the grout. The well will stand for 24 hours to insure that the annular seal has cured. A sample of the grout will be placed in a container under water and checked as proof the grout has set before additional drilling will be allowed to continue.

The field geologists and drillers will be trained in-house and then in the field with practical application of the Halliburton cementing procedures. Field personnel will not be allowed to attempt grouting until the ESE Geotechnical Supervisor verifies their qualification. The supervisor will then observe placement to confirm that cementing is done according to specification.

Prepared by,

Zachary A. Smith /MEM

Zachary A. Smith, P.E.
Task Manager

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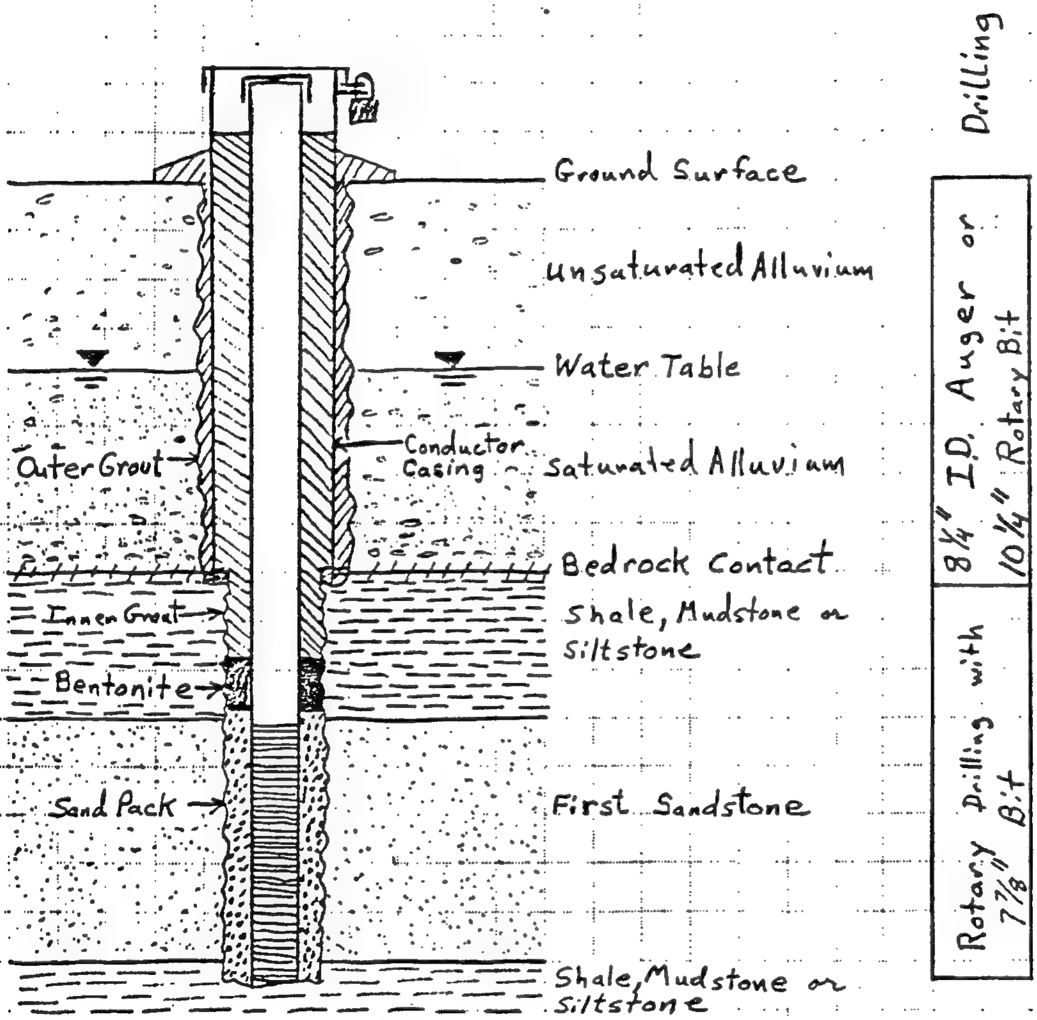
(303) 741-0639

JOB RMA 4" Monitoring Well, Denver Fm
SHEET NO. 1 OF 7
CALCULATED BY Roy L. Cox DATE Nov. 24, 1986
CHECKED BY DATE
SCALE None

DENVER FM. WELL COMPLETED in FIRST SANDSTONE, Alluvium Saturated, Shale at the Alluvial-Bedrock Contact.



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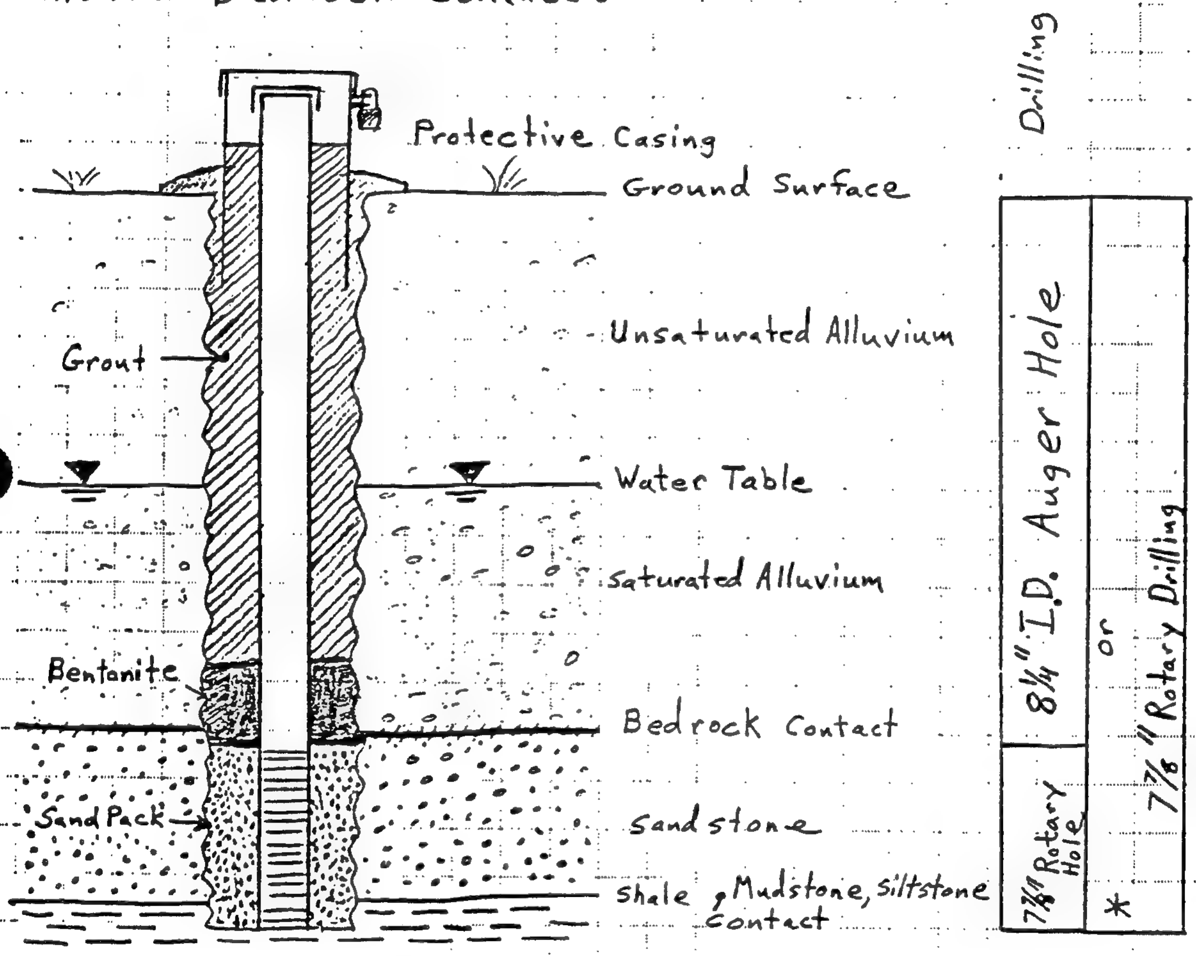
JOB RMA 4" Monitoring Wells, Denver Fm
SHEET NO. 2 OF 7
CALCULATED BY Roy L. Cox DATE Nov. 24, 1986
CHECKED BY ______ DATE ______
SCALE None

DENVER FM. WELL COMPLETED in FIRST SANDSTONE, Alluvium Saturated, Sandstone at the Alluvial-Bedrock Contact.



*Field Determination after Drilling Alluvium

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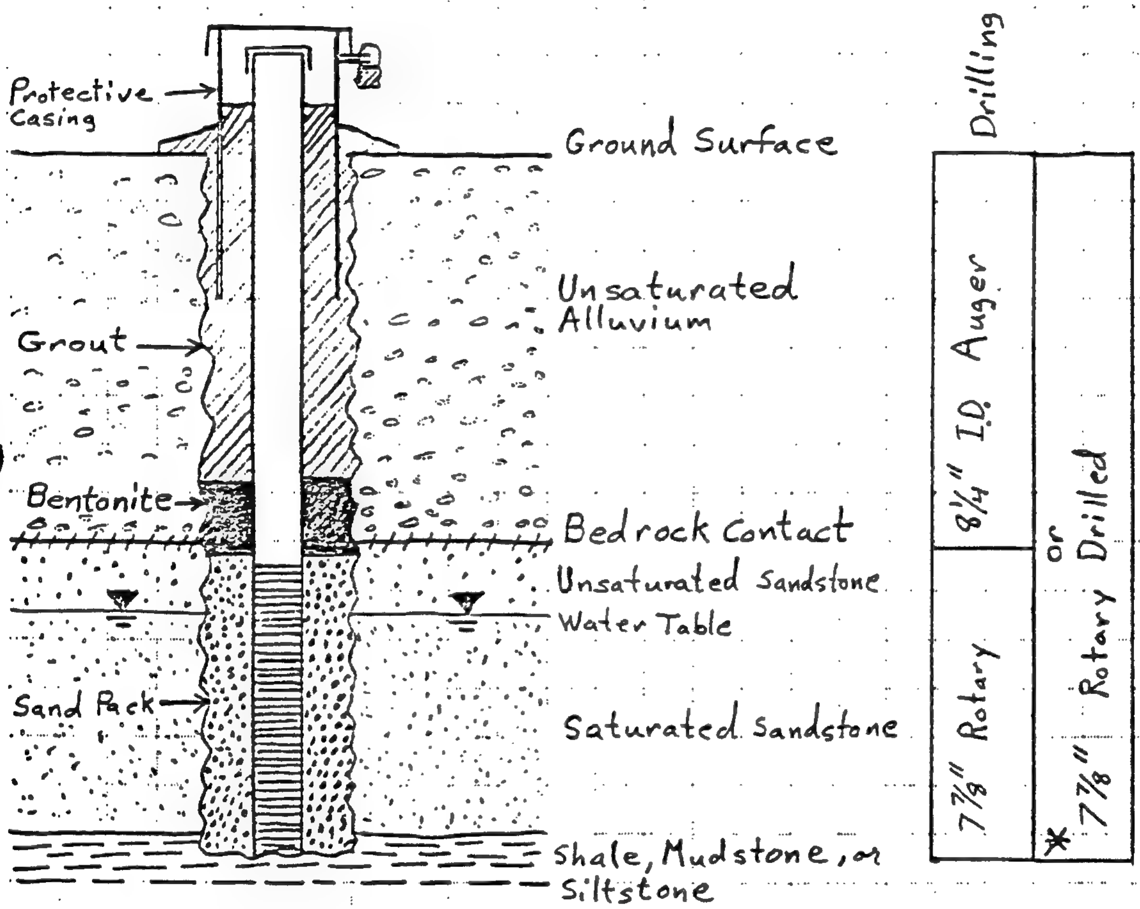
JOB RMA 4" Monitoring Wells, Denver Fm
SHEET NO. 3 OF 7
CALCULATED BY Roy L. Cox DATE Nov. 24, 1986
CHECKED BY DATE
SCALE None

DENVER FM. WELL COMPLETED in FIRST SANDSTONE, Alluvium Unsaturated, Sandstone at the Alluvial-Bedrock Contact; Sandstone Partially Saturated.



* Field Determination after Drilling Alluvium

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AND ENGINEERING, INC.
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Englewood, Colorado 80112
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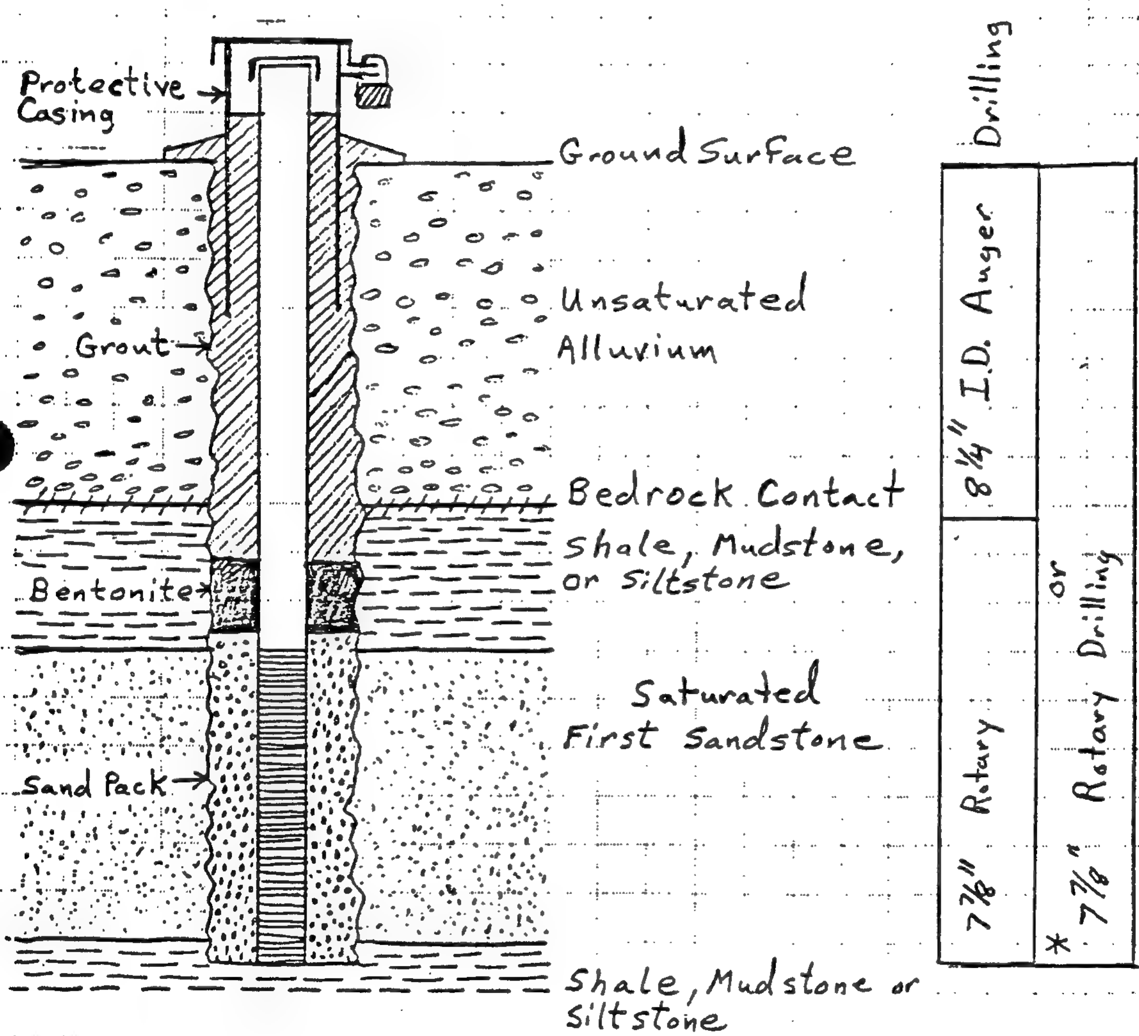
JOB RMA 4" Monitoring Wells, Denver Fm
SHEET NO. 4 OF 7
CALCULATED BY Roy L. Cox DATE Nov. 24, 1986
CHECKED BY DATE
SCALE None

DENVER FM. WELL COMPLETE in the FIRST SANDSTONE, Alluvium Unsaturated, Shale at the Alluvial-Bedrock Contact



* Field Determined after Drilling Alluvium

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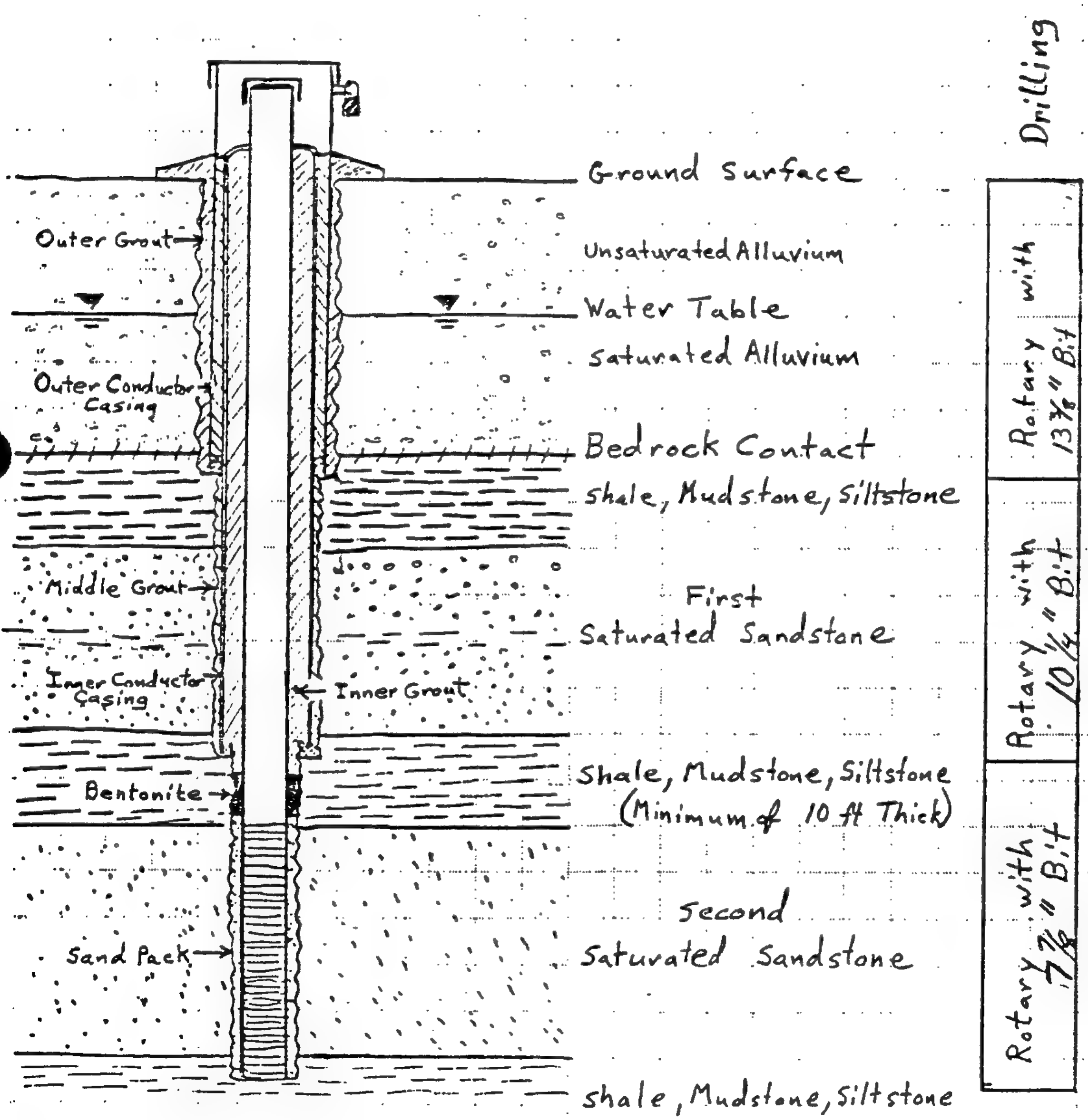
DENVER FM. WELL COMPLETED in SECOND SANDSTONE, Alluvium Saturated, Shale at the Alluvial-Bedrock Contact.



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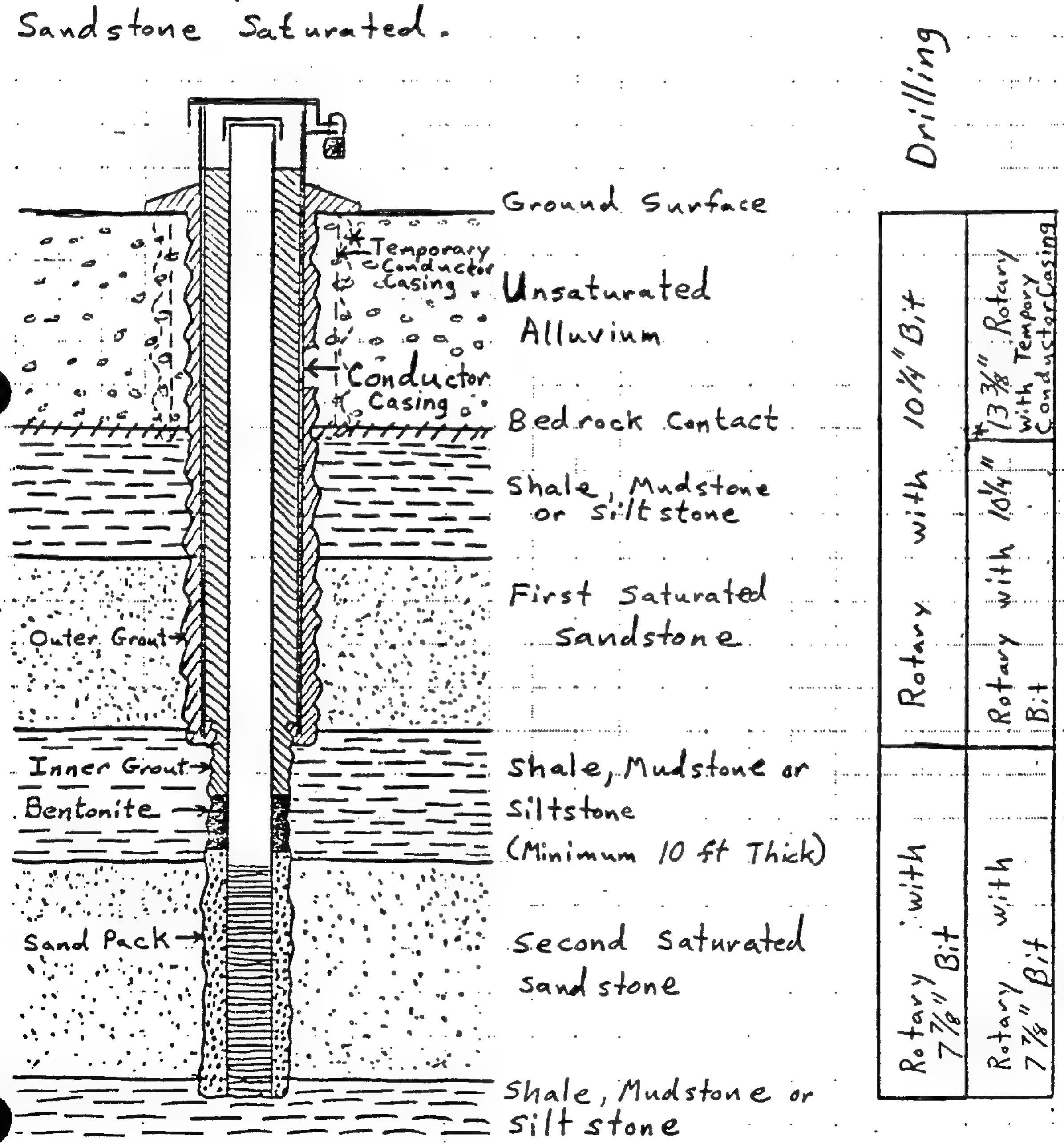
JOB RMA 4" Monitoring Wells
SHEET NO. 6 OF 7
CALCULATED BY Roy L. Cox DATE Nov. 24, 1986
CHECKED BY DATE
SCALE None

DENVER FM. WELL COMPLETED in the SECOND SANDSTONE, Alluvium Unsaturated, Shale at the Alluvial-Bedrock Contact, First and Second Sandstone Saturated.



* Field Determination after Drilling Alluvium

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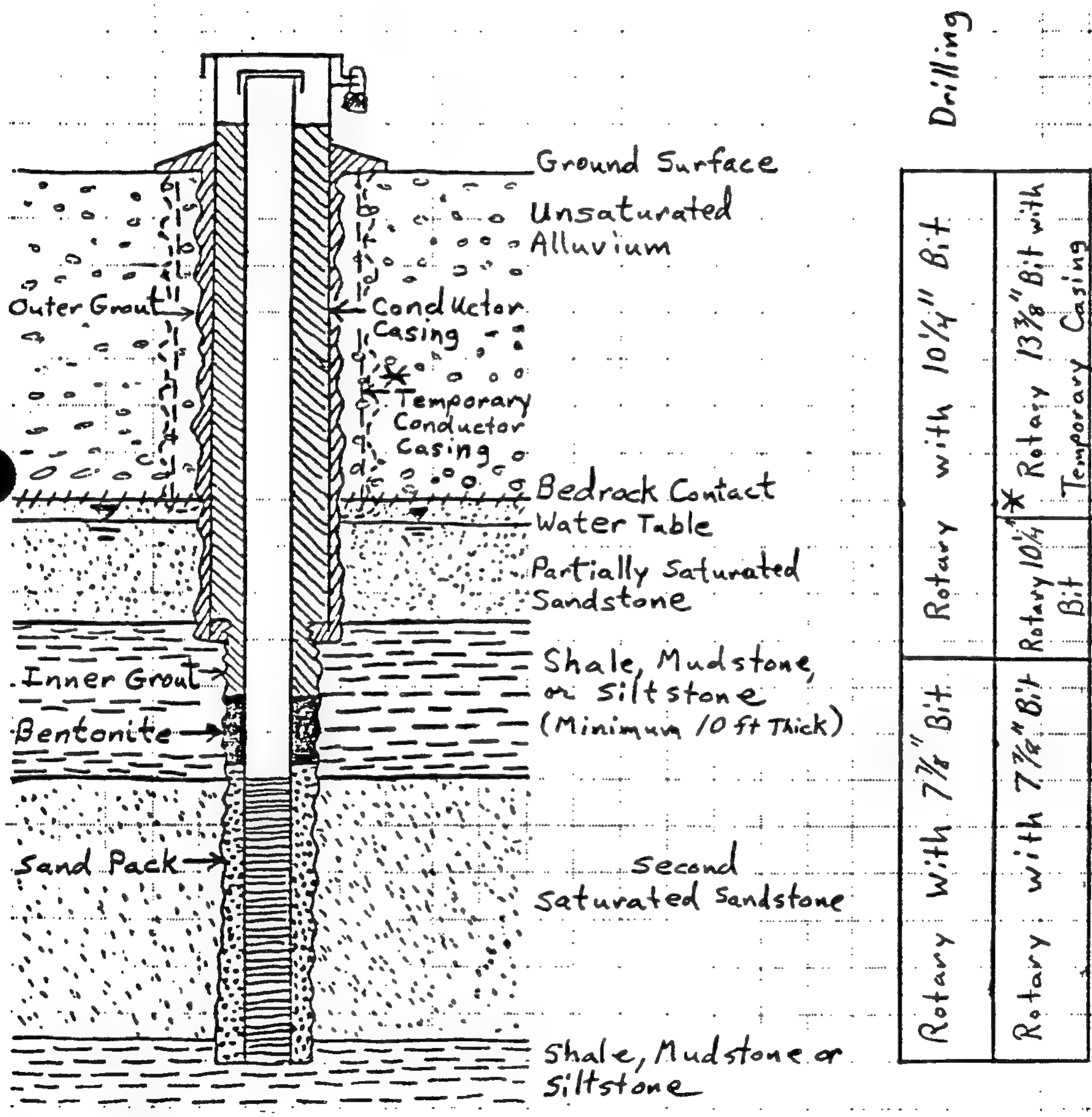
JOB RMA 4" Monitoring Wells Denver F.
SHEET NO. 7 OF 7
CALCULATED BY Roy L. Cox DATE Nov. 24, 1986
CHECKED BY ____ DATE ____
SCALE None

DENVER FM. WELL COMPLETED in the SECOND SANDSTONE, Alluvium Unsaturated, Saturated Sandstone at the Alluvial-Bedrock Contact



* Field Determination after Drilling Alluvium

ESE

AN RS&H. COMPANY

ENVIRONMENTAL SCIENCE
AND ENGINEERING, INC.

August 14, 1986
Project No. 86942, 86946, and Task 36

Letter Technical Plan

Office of the Program Manager
Rocky Mountain Arsenal Contamination Cleanup
ATTN: AMXRM-EE (Mr. Charlie Scharmann)
BLDG: E-4585, Double Trailer
Aberdeen Proving Ground, Maryland 21010-5401

Re: Combined Offpost Borehole and Monitor Well Drilling Program
Task 25, 36, and 39

Dear Charlie:

ESE, Inc. has prepared a comprehensive drilling program incorporating elements of the borehole/corehole and monitor well drilling programs of Tasks 25, 36, and 39. This proposed Offpost drilling program was prepared by a committee composed of ESE's hydrogeologist, geochemists, geologists, and engineers involved in each of these tasks. Also, comments and recommendations made by Brian Anderson of the RMA-PMO, James May of the Corps of Engineers, and yourself have been considered and incorporated into the proposed drilling program.

Briefly, the proposed drilling program is designed to be flexible yet still provide adequate geologic ground water and geochemical information.

The location of well sites, the number of wells per site, and completion intervals for each well are not rigidly fixed at this point. Well sites which appear on the enclosed map, Attachment A, represent the general location where data is needed and where physical access is best. The precise location of wells will depend on the U.S. Army Corps of Engineers obtaining right of entries, access ways and right-of-ways, and results of the geophysics and borehole/corehole drilling.

The boreholes/coreholes and monitoring wells will be completed in both the alluvial material and the sandstones of the Denver Formation. Cluster well sites will consist of one alluvial well paired with one or two Denver Formation wells. At sites with 2 Denver wells, the wells will be completed within the first and second sandstone aquifers encountered during drilling.

The installation of Denver Formation monitoring wells will be concentrated within an area 1½ miles north of the arsenal and west of Potomac Street to Colorado Route 2. The Denver wells are concentrated in this area since this area is where the Denver sandstones which subcrop under RMA also subcrop in the Offpost.

7332 South Alton Way, Suite H Englewood, Colorado 80112 303/741-0639

Enclosed you will find copies of the following materials:

1) Map titled "Proposed Well and Boring Sites with Locations of Existing Wells", Attachment A;

2) Table titled "Proposed Activities at Drill Sites", Attachment B; and

3) Site descriptions.

Copies of this letter and the enclosed materials are being forwarded to the following MOA committee members:

-Connally Mears of EPA
-Larry Ford of South Adams County Water and Sanitation District
-Chris Sutton of Colorado Health Department
-Kenneth Conright of Tri-County District Health Department
-William Adcock of Shell Chemical Company

If you or any MOA committee member have any questions regarding the offpost drilling program, please address them to either John Dreier, Roy L. Cox, or Mark Griswold.

Sincerely,

Roy L. Cox

Roy L. Cox
CPGS #6556

RLC/MB

Enclosures

cc: Connally Mears
Larry Ford
Chris Sutton
Kenneth Conright
William Adcock
John Dreier
Mark Griswold
File

Attachment B

"Proposed Activities at Drill Sites"

ESE Site	Quarter/ Quarter Section Location	*Owner	Existing Well	Geophysics Line	Proposed Number of Wells	COMPLETION DATA Alluvial Well	Intermediate Denver Well	Lower Denver Well
E-32	NW/4 NW/4-24	RMA	24093(All)	No	2	---	yes	yes
-33	NW/4 NW/4-24	RMA	24163(All)	No	2	---	yes	yes
-34	SE/4 SW/4-13	A	37338(All)	No	2	---	yes	yes
-35	NE/4 NE/4-24	RMA	-	No	bore only	---	---	---
-36	SE/4 SE/4-13	A	-	yes	3	yes	yes	yes
-37	SE/4 SE/4-15	A	-	yes	3	yes	yes	yes
-38	SW/4 SW/4-14	S	-	yes	(2-3)	may be dry	yes	yes
-39	SE/4 SW/4-14	P	-	yes	3	yes	yes	yes
-40	SW/4 SE/4-14	P	37305	No	2	---	yes	yes
-41	SE/4 SE/4-14	P	37304	No	2	---	yes	yes
-42	SE/4 SE/4-14	P	-	No	3	yes	yes	yes
-43	NE/4 SW/4-14	P	-	yes	bore only	---	---	---
-44	NW/4 SE/4-13	P	-	yes	3	yes	yes	yes
-45	NW/4 SW/4-13	A	37323	yes	2-3	?	yes	yes
-46	NW/4 SW/4-13	P	-	yes	3	yes	yes	yes
-47	NE/4 SW/4-13	P	-	yes	3	yes	yes	yes
-48	NW/4 SE/4-13	P	-	yes	bore only	---	---	---
-49	NW/4 SW/4-18	A	37327	No	2	---	yes	yes
-50	SW/4 NE/4-14	S	-	yes	1	yes	---	---
-51	NW/4 NE/4-14	S	37342	yes	2	---	yes	yes
-52	SE/4 SE/4-11	A	-	yes	1	yes	---	---
-53	SW/4 SE/4-12	A	-	yes	3	yes	yes	yes
-54	SW/4 SE/4-12	A	-	yes	3	yes	yes	yes
-55	NE/4 SW/4-22	A?/P?	-	yes	1	yes	---	---
-56	NE/4 SE/4-15	P	-	yes	1	yes	---	---
-57	SW/4 SE/4-11	S	-	yes	1	yes	---	---
-58	NE/4 SE/4-11	A	-	yes	1	yes	---	---
-59	SE/4 NW/4-12	S	-	yes	1	yes	---	---
-60	SW/4 NW/4-15	UP/RR	-	yes	1	yes	---	---
-61	SW/4 SW/4-11	A	-	---	1	yes	---	---
-62	SE/4 NW/4-11	P	-	yes	1	yes	---	---
-63	SW/4 SW/4-13	P	-	yes	3	yes	yes	yes
-64	NW/4 NW/4-13	A	-	yes	3	yes	yes	yes

*Owner Code

P=Private Owner
S=State Hwy. Dept.
RMA=Rocky Mountain Arsenal
A=Adams County Hwy. Dept
UP/RR=Union Pacific Railroad

ATTACHMENT C

SITE DESCRIPTIONS

INTRODUCTION

This is to request access to Colorado Department of Highways owned right-of-way along Highway 2 and Highway 44 (East 104th Avenue west of Highway 2). Access will be needed for the purpose of ground water monitoring activities. These will include the drilling of boreholes and the installation of monitoring wells as well as long-term ground water sampling of the wells on a quarterly basis. Access will be needed for six sites which are described by Section as follows.

<u>Section 14 (T2S, R67W)</u>

E-38 is a site for the installation of a cluster of three wells along the west side of Highway 2, approximately 1,200 feet (ft) northeast of the intersection of East 96th Avenue. The site is 900 ft east of the west section line and 900 ft north of the south section line lying in the southwest quarter, southwest quarter of Section 14.

E-50 is a site for the installation one or more wells along the west side of Highway 2. It is 3,100 ft east of the west line and 3,500 ft north of the south line of Section 14 and lies in the southwest quarter, northeast quarter of Section 14.

E-51 is at the site of an existing shallow well where an additional 1 or 2 wells will be installed. The site is approximately 3,800 ft east of the west line and 4,300 ft north of the south line of Section 14 in the northwest quarter, northeast quarter of Section 14.

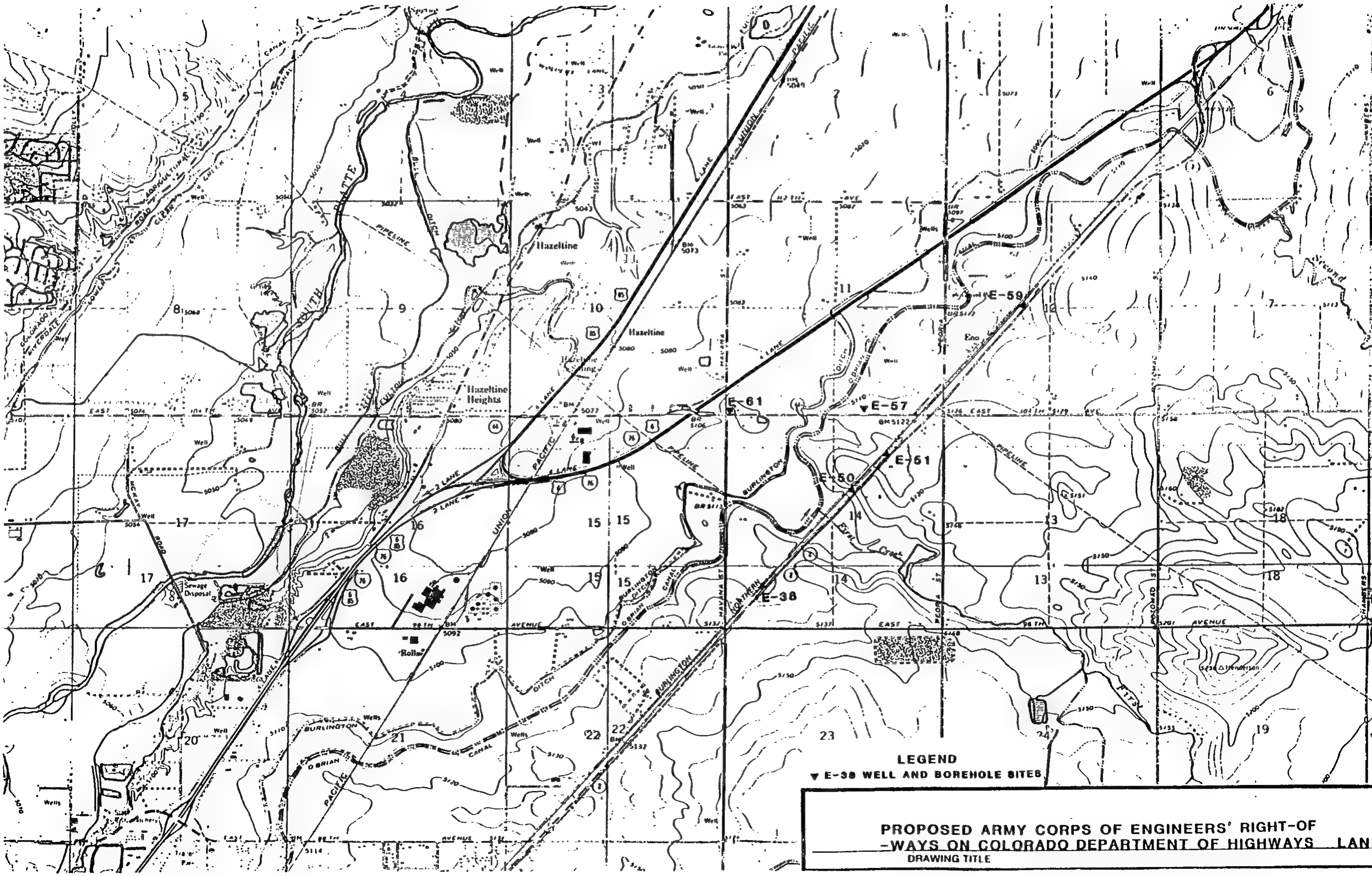
<u>Section 11 (T2S, R67W)</u>

Site E-57 is along the north side of Highway 44 (East 104th Avenue west of the junction with Highway 2) which runs along the south line of Section 11. The site is about 3,500 ft east of the west line and 30 ft north of the south line lying in the southwest quarter, southeast quarter of Section 11.

Site E-61 also is along the north side of Highway 44 approximately 100 ft east of the west line and 30 ft north of the south line in the southwest quarter, southwest quarter of Section 11.

Section 12 (T2S, R67W)

Site 59 lies along the northwest side of Highway 2, approximately 1,900 ft east of the west line and 2,800 ft north of the south line in the southeast quarter, northwest quarter of Section 12.



LEGEND

▼ E-38 WELL AND BOREHOLE SITES

PROPOSED ARMY CORPS OF ENGINEERS' RIGHT-OF-WAYS ON COLORADO DEPARTMENT OF HIGHWAYS LAND

DRAWING TITLE

INTRODUCTION

This is to request access to Adams County owned highway right-of-way for the purpose of ground water monitoring activities. This will include the drilling of boreholes and the installation of monitoring wells as well as long-term ground water sampling on a quarterly basis. Access is needed for nine sites along the following county roads: Havana, Peoria, and Potomac Streets and East 96th and East 104th Avenues. These sites are described by Section as follows.

Section 15 (T2S, R67W)

Site E-37 is along the west side of Havana Street, 800 ft north of the south line and approximately 20 ft west of the east line of Section 15 and is in the southeast quarter, southeast quarter of Section 15.

Section 13 (T2S, R67W)

Site E-34 is along the north side of East 96th Avenue at an existing shallow monitor well site that is 2,500 ft east of the west line and 20 ft north of the south line in the southeast quarter, southwest quarter of Section 13.

Site E-36 is along the west side of Potomac Street approximately 20 ft west of the east line and 500 ft north of the south line in the southeast quarter, southeast quarter of Section 13.

Site E-45 is along the east side of Peoria Street about 20 ft east of the west line and 2,700 ft north of the south line of Section 13 lying in the northwest quarter, southwest quarter of Section 13.

Site E-64 is along the east side of Peoria Street approximately 4,000 ft north of the south line and 20 ft east of the west line of Section 13. The site lies in the northwest quarter, northwest quarter of Section 13.

Section 18 (T2S, R66W)

Site E-49 lies along the east side of Potomac Street about 2,600 ft north of the south line and 20 ft east of the west line in the northwest quarter, southwest quarter of Section 18.

Section 12 (T2S, R67W)

Site E-53 is along the north side of East 104th Avenue approximately 900 ft east of the west line and 20 ft north of the south line in the southwest quarter, southwest quarter of Section 12.

Site E-54 is along the north side of East 104th Avenue approximately 3,300 ft east of the west line and 20 ft north of the south line in the southwest quarter, southeast quarter of Section 12.

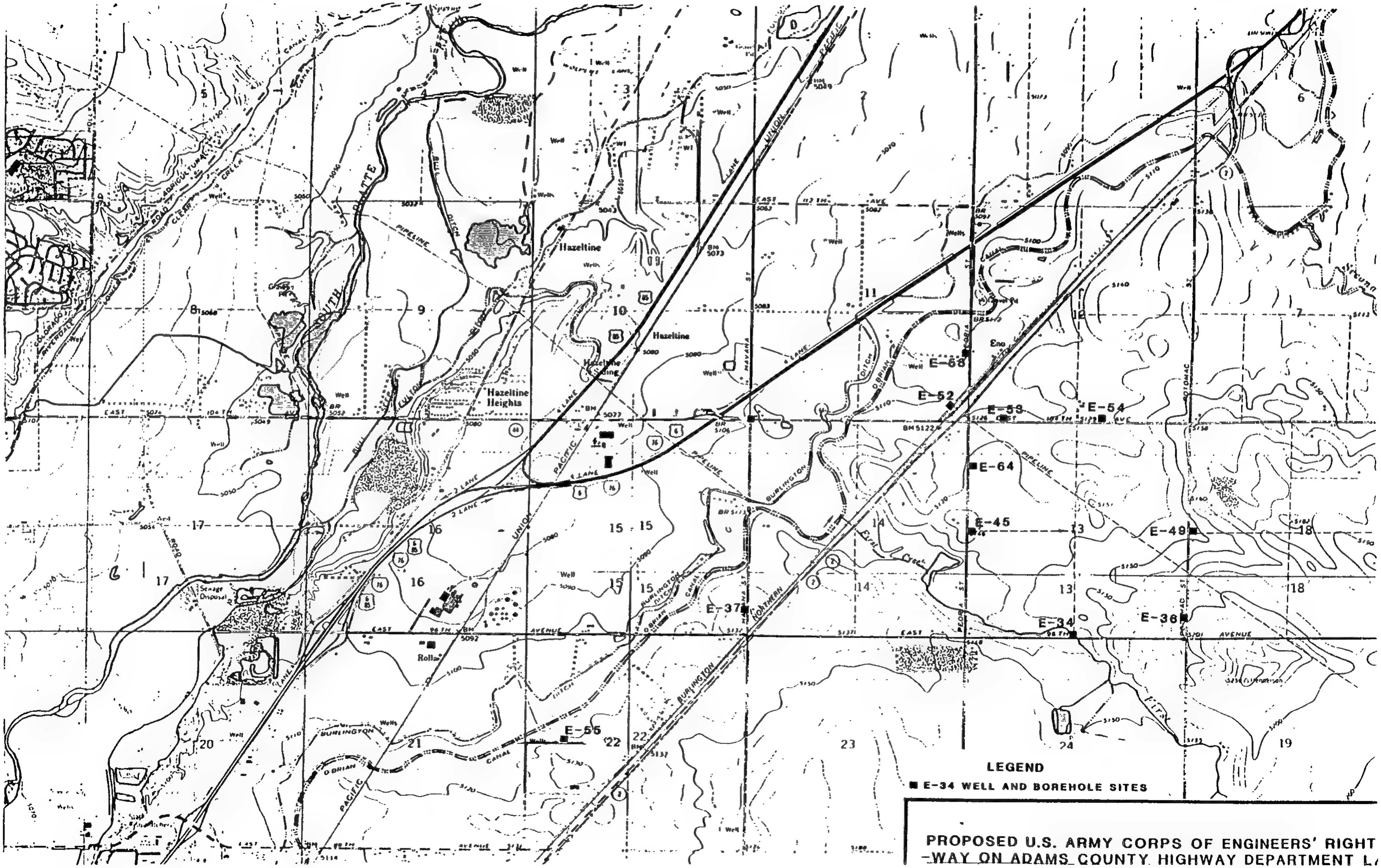
Section 11 (T2S, R67W)

Site E-52 is along the northwest side of Peoria Street approximately 500 ft northeast of the intersection with East 104th Avenue. This site is in the southeast quarter, southeast quarter of Section 11 approximately 400 ft west of the east line and 400 ft north of the south line of Section 11.

Site E-58 is along Peoria Street on the west side about 1,700 ft north of the south line and 20 ft west of the east line in the northeast quarter, southeast quarter of Section 11.

SECTION 22 (T2S, R67W)

Site E-55 is along East 92nd Avenue on the north side of the roadway. The site is in the southwest quarter, northwest quarter of Section 22 approximately 2,700 ft north of the south line and 1,200 ft east of the west line. (This site may be on Burlington Northern Railroad property. See private ownership section [Section 22]).



PROPOSED U.S. ARMY CORPS OF ENGINEERS' RIGHT
-WAY ON ADAMS COUNTY HIGHWAY DEPARTMENT L

INTRODUCTION

This is a request for easement and access onto privately owned property for the purposes of ground water monitoring activities. The proposed activities will include any or all of the following: preliminary geophysical surveys, the drilling of boreholes, the installation and completion of monitoring wells, and the long-term sampling of ground water in the wells on a quarterly interval. The exact locations of borehole sites is dependent upon the completion of the preliminary geophysical surveys. The locations of most of the permanent monitor well installations will hinge upon the data collected both in the geophysical and borehole programs. Some sites have been pre-selected because of the location of an existing monitoring well, but most sites were selected to minimize disturbance and inconvenience to private land owners by being placed along property boundaries and fence lines where practical. All sites will be regraded and seeded to return the site to original condition. Permanent well sites will cover a 5 foot to 20 foot square area. These sites will contain one to three wells completed in the alluvium and/or the Denver Formation.

The individual sites and property owners involved are listed below by Section as well as a discussion of the activity level anticipated for each site. A detailed description of each type of activity is included at the end to indicate the type of short-term and long-term access needed as well as the amount of short-term physical disturbance and the long-term presence of physical objects such as well casings.

SITE LOCATIONS

Section 13 (T2S, R67W)

E-43, E-46, E-47, and E-63 are sites located on property denoted by tax record 1721-00-0-00-030 in the southwest quarter of Section owned by:

Adams County Joint Venture
℅ Butler and Pierce
720 Kipling Street, Suite 201
Lakewood, Colorado 80215
(303) 232-3888

A fifty foot easement and corridor of access is requested along the northern, eastern and southwestern property lines of the property to conduct a preliminary geophysical survey to drill several borings and install monitoring wells. Site E-46, E-47, and E-63 are the proposed well locations. There will be three wells installed at each of the well sites. E-43 is the location of a borehole site. We will be requesting continued access along the north and southwest corridors for quarterly monitoring (every 3 months). The exact locations for these wells and bores will be determined after the completion of the geophysical survey.

Section 14 (R2S, R67W)

Site E-39 is located on property denoted by tax record 1721-14-0-05-005 in the southeast quarter of the southwest quarter of Section 14 owned by:

City of Commerce City
% Gregg Clements
4407 E. 60th Avenue
Commerce City, Colorado 80022
(303) 289-3701

Currently being dryland wheat farmed by Hickey Farms

% Charles Hickey
3240 Jay Street
Wheatridge, Colorado 80033
(303 233-9003

A 50 ft easement and corridor of access is requested for the eastern property line of Block 5 of the Adco Industrial Park Subdividion in Section 14 which runs from the center point of Section 14 due south to the midpoint of the south section line of Section 14 (96th Avenue). This is needed to run a preliminary geophysical survey, drill a boring and install a permanent cluster of three monitor wells at or near site E-39.

Site E-48 is located on property denoted by property tax record number 1721-00-0-00-007 in the center of the east half of Section 13 on property owned by:

Box Elder Farms Company
1125 17th Street, Suite 2500
Denver, Colorado 80202
(303) 371-5026

A 50 ft easement is requested for temporary access along a corridor from the center point of Section 13 due eastward to the east section line (Potomac Street) for the purpose of running preliminary geophysics and drilling one or more borings. It is planned at this time to drill the proposed boring(s) and then abandon the site following approved well abandonment and reclamation procedures. No further access is expected after the boring(s) are completed.

Site E-40 is located on property denoted by tax record number 1721-14-0-04-020 in the southwest quarter of the southeast quarter of Section 14, approximately 2,000 ft west of the east line and 1,300 ft north of the south line. This property is owned by:

Michael Bruce Collins
11515 East 96th Avenue
Commerce City, Colorado 80022
(303) 288-5969

The access to this property is needed to install two more monitoring wells adjacent to an existing shallow well after an initial boring is completed at the site. An easement of 20 ft along the eastern edge of the property or a satisfactory route chosen by the land owner is requested. Future access to sample this well cluster will be needed on a periodic basis.

Site E-41 is located on property denoted by tax record number 1721-14-0-04-019 which lies in the southeast corner of the southeast corner of Section 14 approximately 1,300 ft west of the east line and 600 ft north of the south line and is owned by:

Dorothy Lambert
11921 East 96th Avenue
Commerce City, Colorado 80022
(303) 287-2733

The access to this site is needed to drill a boring and install two monitoring wells adjacent to an existing shallow monitoring well. The total permanent area of disturbance would be a 20 ft by 20 ft area adjacent to the fence. Future access to the cluster of wells would be needed for periodic ground water sampling on a quarterly basis. This land is currently up for sale by the owner.

Site E-42 is located on property denoted by tax record number 1721-14-0-04-015 in the southeast quarter of the southeast quarter of Section 14, approximately 400 ft west of the east line and 660 ft north of the south line. The property is owned by:

Dorothy Lambert
11921 East 96th Avenue
Commerce City, Colorado 80022
(303) 287-2733

A 50 ft easement and corridor of access along the northern boundary of the property or any other suitable route of access as directed by the property owner is requested to gain access to the site to drill a test boring and install a cluster of three monitor wells. Total permanent disturbance will be an area around the well cluster 20 ft by 20 ft. Future access on a quarterly basis to sample the wells will be needed.

Site E-44 is located on property denoted by tax record number 1721-14-0-00-027 in the northwest quarter of the southeast quarter of Section 14 approximately 1,600 ft west of the east line and 1,900 ft north of the south line. This property is owned by:

Charles Hickey and Michael E. Hickey
3240 Jay Street
Wheatridge, Colorado 80033
(303) 233-9003

We are requesting access to this site along a 40 ft wide easement along the drainage of First Creek southeastward from Highway 2 or along any other suitable corridor as suggested by the property owner. Access is needed to conduct a preliminary geophysical survey along the corridor to drill a test boring in a suitable site at or very near the proposed site based on the geophysics, and to install and complete a cluster of two to three monitor wells. The total area of permanent disturbance will be a 20 ft by 20 ft area around the well cluster. In addition, future access to the monitor well site for quarterly sampling will be needed.

Section 22 (T2S, R67W)

Site E-55 is on property denoted by tax record number 1721-22-0-05-001 in the northeast quarter of the southwest quarter of Section 22 approximately 1,500 ft east of the west line (Yosemite street) and 2,600 ft north of the south line (East 88th Avenue) along the south side of East 92nd Avenue on property owned by:

Burlington Northern Railroad
% ATTN: V.D. McKnire
777 Taylor Room 906
P.O. Box 943
Ft. Worth, Texas 76101

Access to this site is requested along an easement coinciding with the proposed location of East 92nd Avenue from Yosemite Street. The access is needed to drill a test boring and install a monitor well or cluster of wells. Future access to sample the ground water in this well(s) will be needed. (This property may be a right-of-way owned by Adams County. See Adams County Section).

Section 15 T2S, R67W)

Site E-56 is located on land denoted by property tax record number 1721-15-0-00-020 in the northeast quarter of the southeast quarter of Section 15 approximately 1,500 ft west of the east line and 2,000 ft north of the south line. This property is owned by:

C-RMA-39D/WPACES.10
10/09/86

Mollie Heinze
% Dave Heinze
10131 E. 96th Avenue
Henderson, Colorado 80640
(303) 268-1600

The site is just northwest of the Burlington Ditch and access is anticipated to be by the "ditch rider road" along the ditch northeastward from E 96th Avenue. A 40 ft corridor of access and easement is requested to conduct a preliminary geophysical survey, drill a test bore, and install and compete one monitoring well at the proposed sit . Total permanent disturbance will be 5 ft by 5 ft area around the well. Future access will be needed for quarterly sampling on a quarterly basis.

Site E-60 is located on property that is the right-of-way of the Union Pacific Railroad Company. Contact:

Union Pacific Railroad Company
Office of Director-Real Estate
Omaha, Nebraska

The proposed site is 50 ft east of the west line and 2,600 ft north of the south line in the northwest corner of the southwest corner of Section 15.

A 50 ft easement and corridor of access is requested located along the side of the railroad tracks to perform a preliminary geophysical survey, drill a test boring and install a monitoring well at or very near the proposed site. The total permanent disturbance will be a 5 ft by 5 ft area around the well. This well will require future access along the railroads access road for quarterly ground water sampling. The well location will be a minimum of 50 ft east of the center line of the railroad tracts.

Section 11 (T2S, R67W)

Site E-62 is located on property denoted by tax record number 1721-11-0-00-008 in the center of Section 11 approximately 2,600 ft south of the north line and 2,600 ft east of the west line of Section 11 on property owned by:

Glenn A. Murray Trust
11010 Havana Street
Route 3, Box 166A
Henderson, Colorado 80640
(303) 288-2998

Access to the site is requested along either of the private roads that run along the east or south boundaries of the property. This will give access from either Havana Street or East 112th Avenue. The site is proposed to be adjacent to the Burlington Ditch. Activities at the site would include preliminary geophysics, a test borehole, and completion and installation of a monitoring well based on the geophysical results. The total permanent disturbance will be an area around the well of 5 ft by 5 ft. Future access to the site is requested for quarterly sampling.

DESCRIPTION OF ACTIVITIES

Geophysics

Running geophysical surveys would entail a short-term access of minimal disturbance from a hand carried instrument or loop of wire that would measure radio frequency impulses. Stations would be surveyed in by a survey crew.

Boreholes

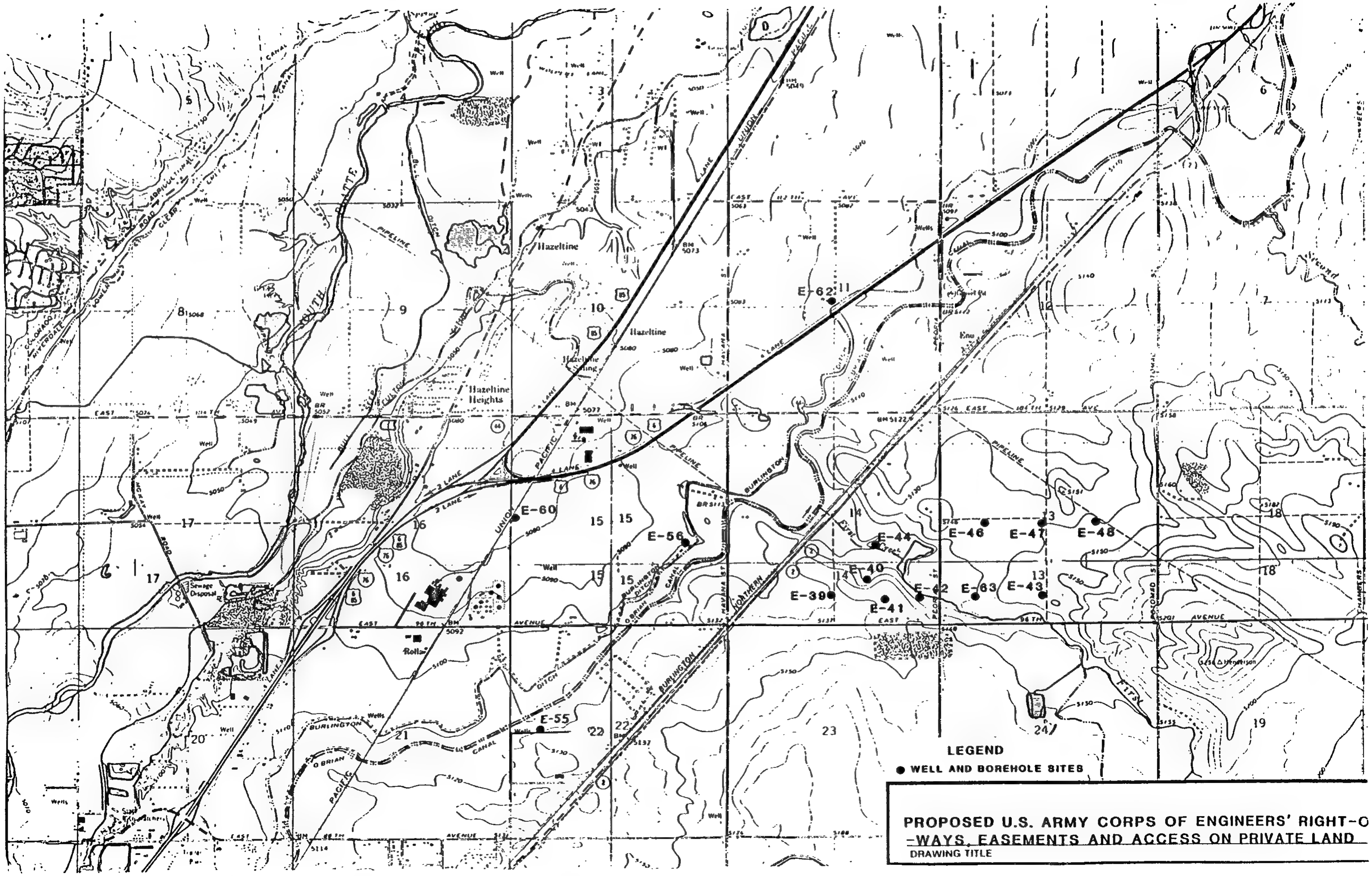
Using data generated during geophysical surveys to pinpoint the most favorable sites for geologic information and monitor well siting, boreholes may be drilled with a medium sized truck-mounted water well drill rig. Support vehicles for drilling would include a water truck and 1 or 2 pickup trucks. Any surface disturbance from boring activities would be regraded and reseeded to pre-site conditions.

Monitor Well Installation

At suitable sites between 1 to 3 monitor wells will be installed in boreholes drilled by the drill rig. The wells will be cased with four inch PVC casing. An eight inch diameter two foot high locked steel protective casing will be installed over the well. Single well sites would only cover an area within a 5 foot square. Cluster well sites with three wells would only cover an area within a 20 foot square. Following the drilling all sites will be regraded and reseeded to correct any minor surface disturbances which may occur.

Long-Term Monitor Well Access

Access to collect periodic ground water samples from the wells on a quarterly basis, would entail access by a one-ton pump truck, a pickup truck with pumping equipment, an ATV (i.e., a 3 or 4 wheel cycle) or even a two person foot mounted crew carrying a small amount of bailing and sampling equipment depending upon access and conditions. Preferred access is by truck followed by ATV and by foot. All attempts at access will be during dry soil conditions to minimize rutting the access way.



LEGEND

● WELL AND BOREHOLE SITES

PROPOSED U.S. ARMY CORPS OF ENGINEERS' RIGHT-O
-WAYS, EASEMENTS AND ACCESS ON PRIVATE LAND

DRAWING TITLE

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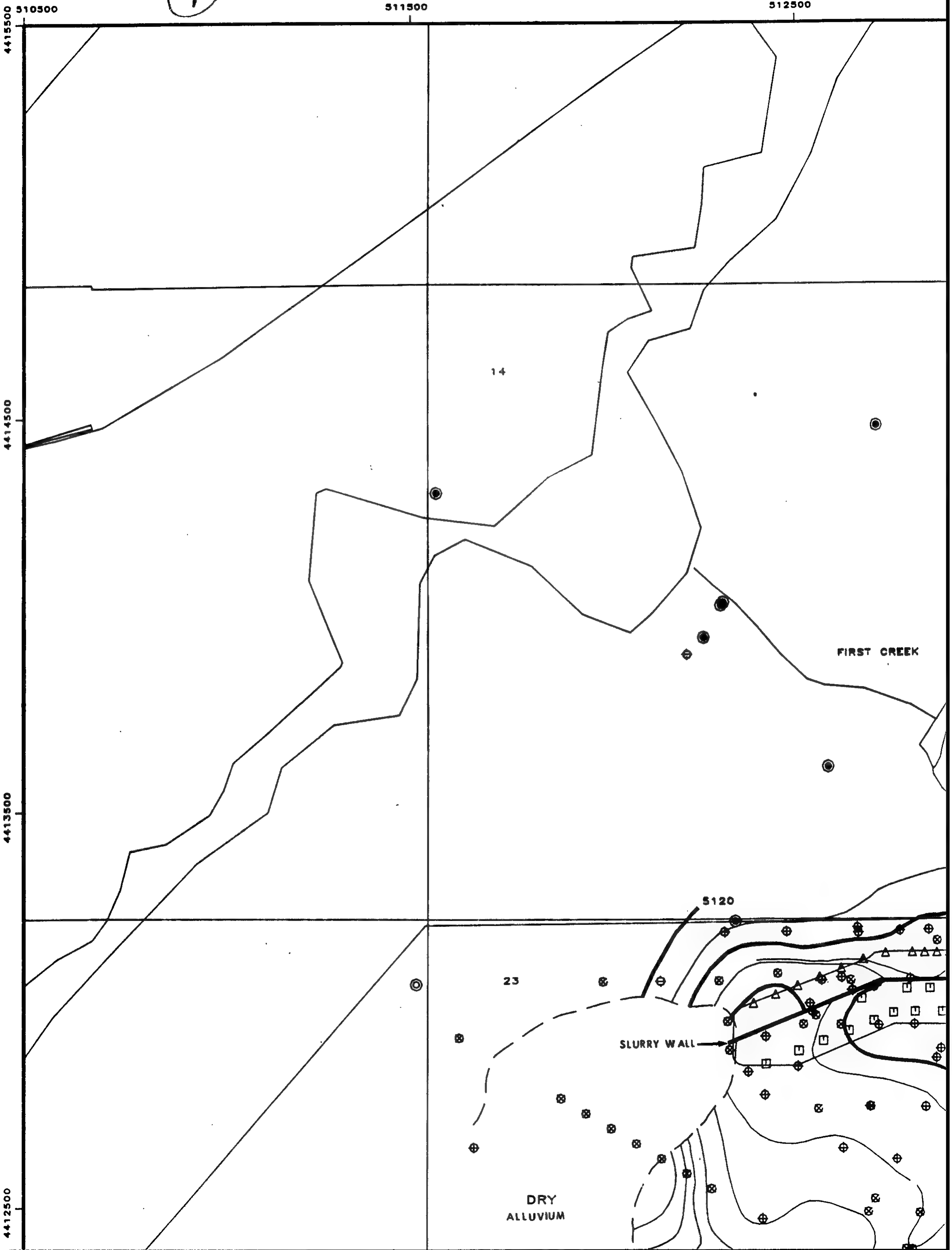

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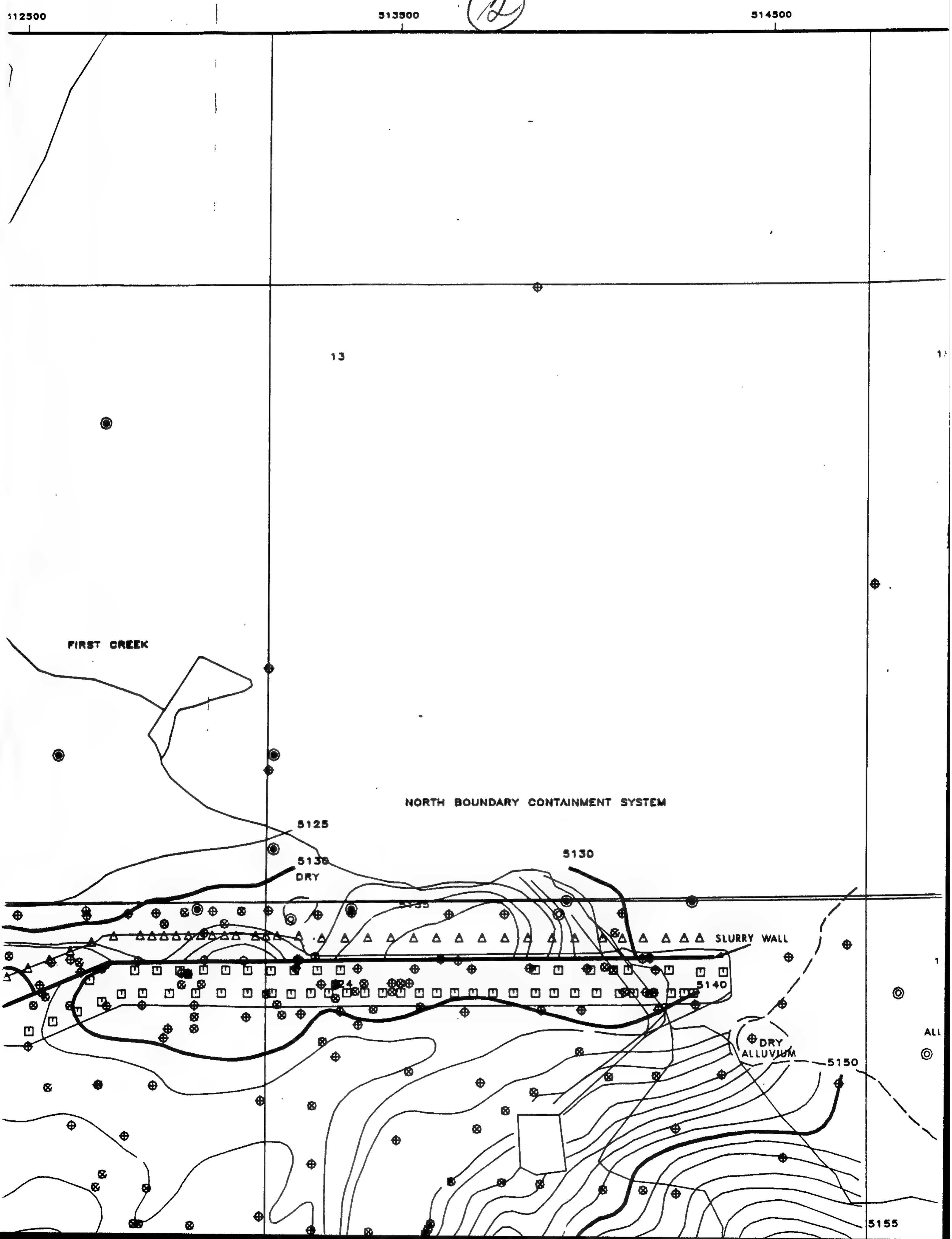

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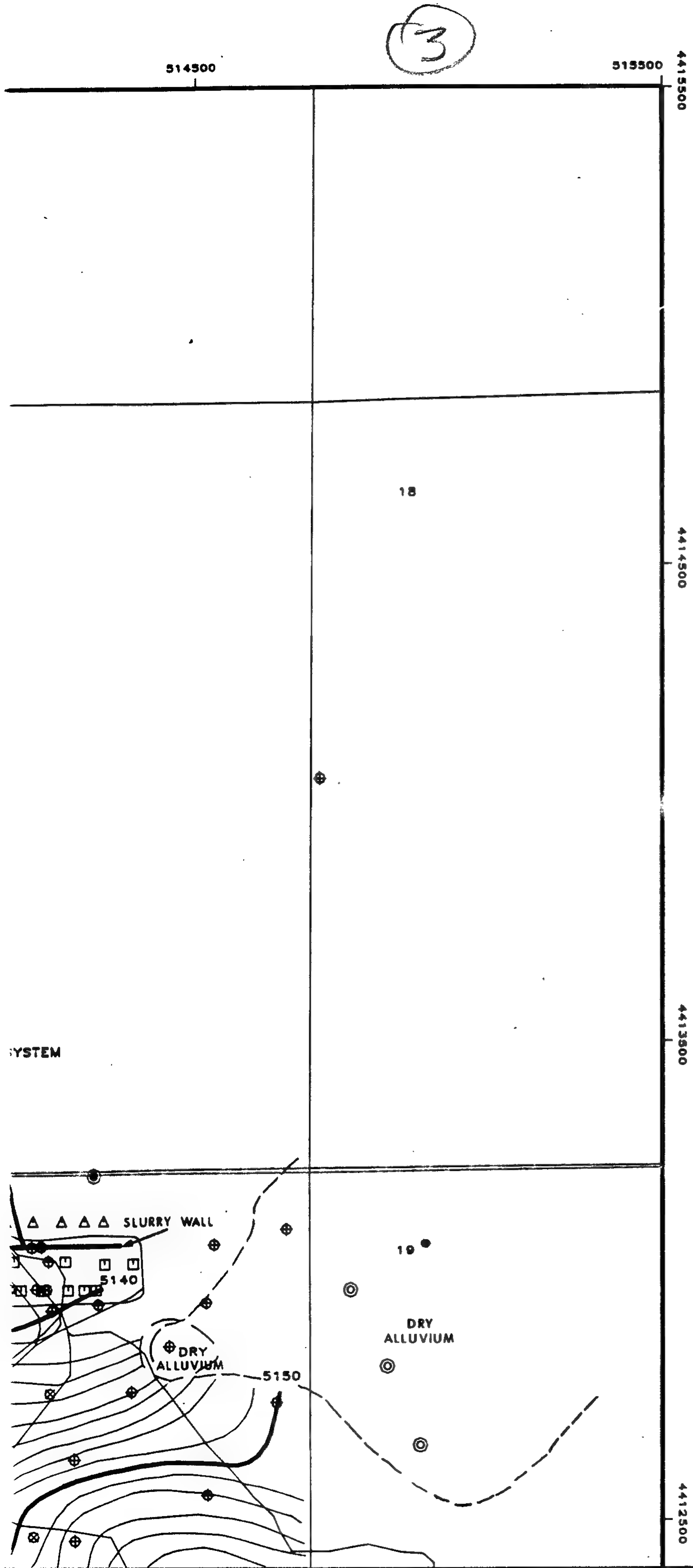

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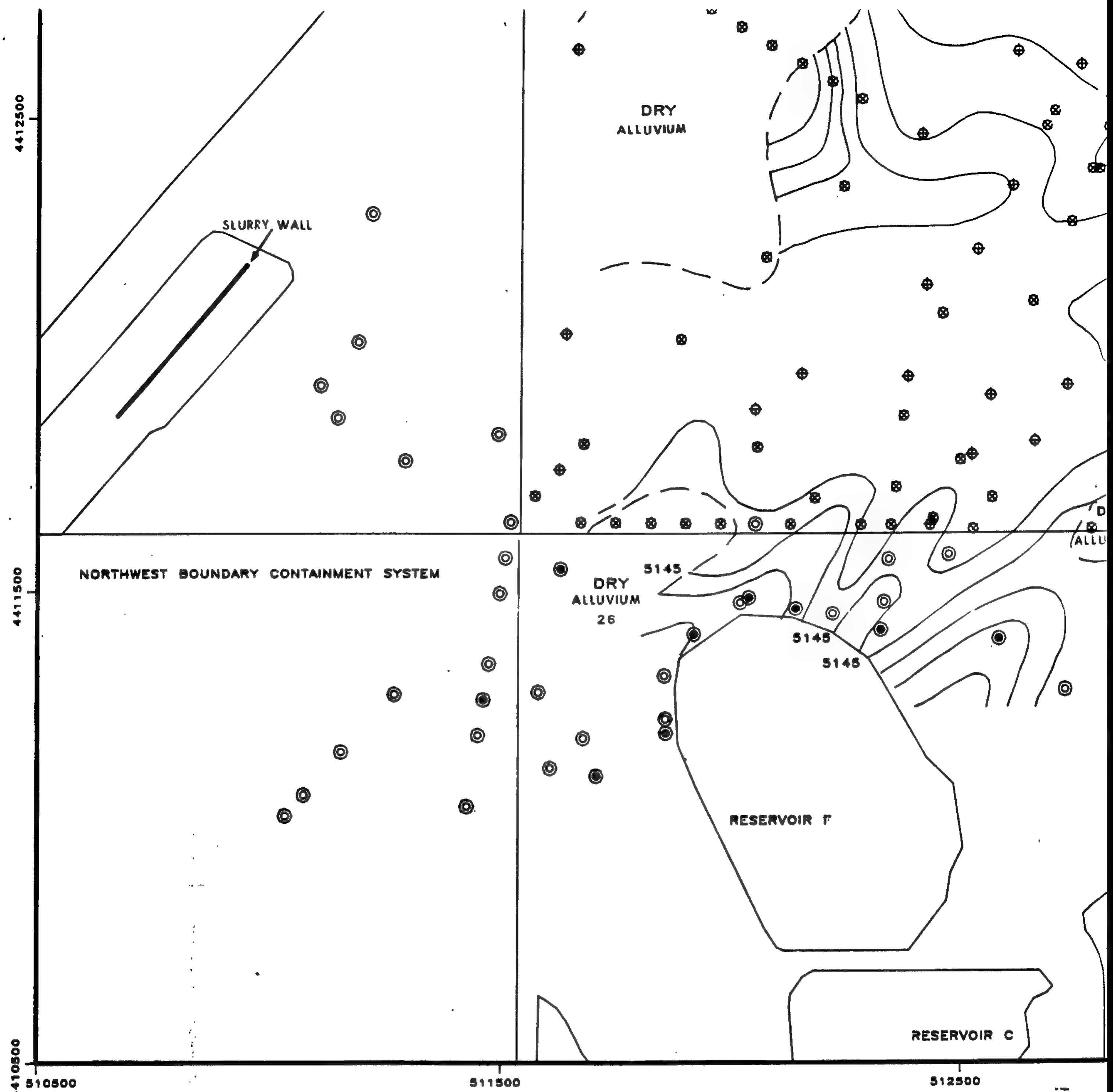
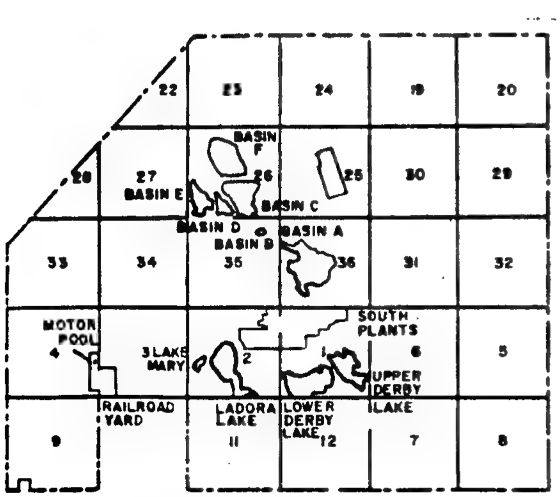


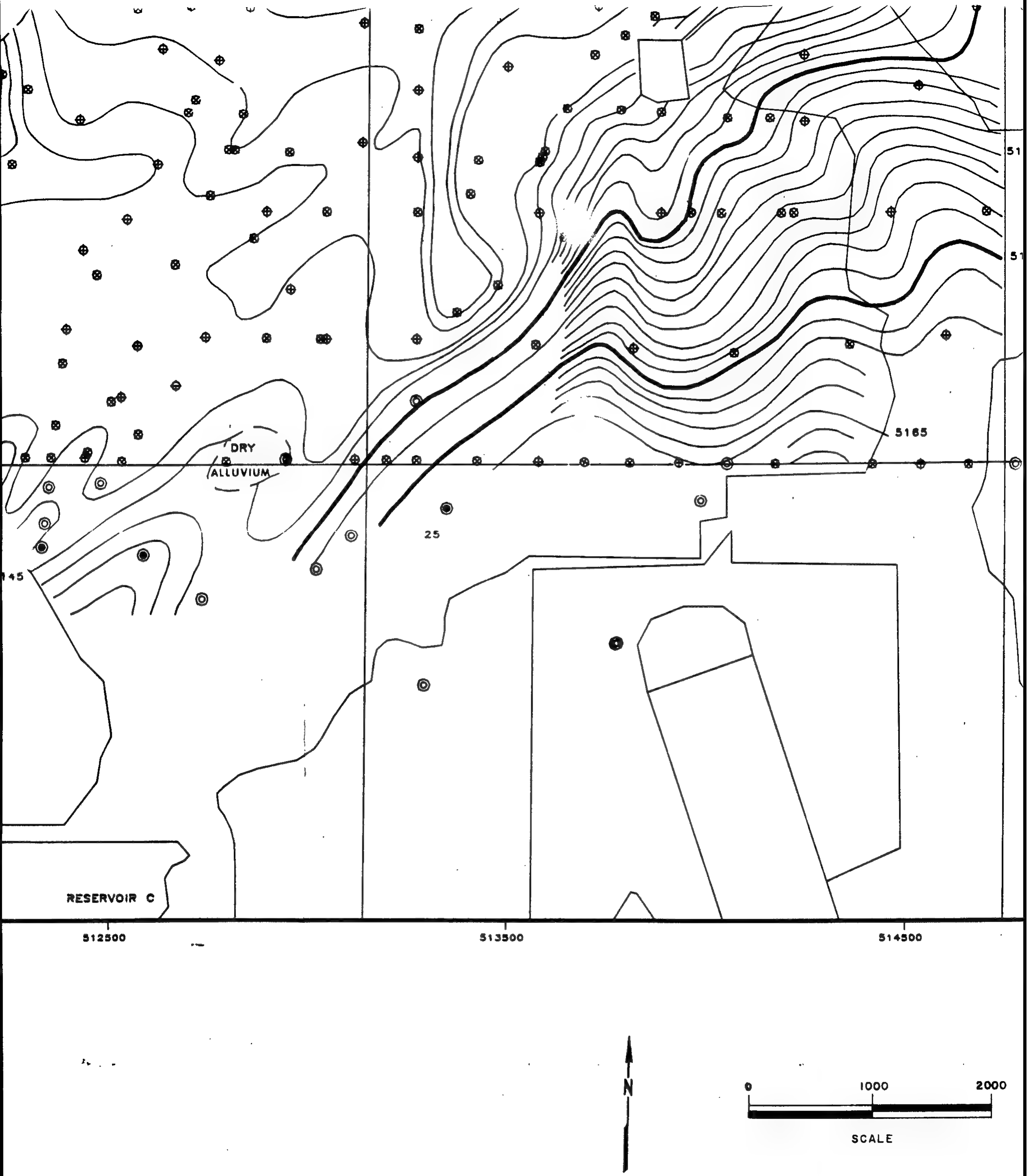


LOCATION MAP

LEGEND

- Injection Well
- Extraction Well
- Task 25 Sampling Well
- Task 25 Water Level Well
- Task 4 Sampling Well
- Task 4 Water Level Well
- Slurry Wall
- Areas Where Alluvium Is Generally Found To Be Dry

4



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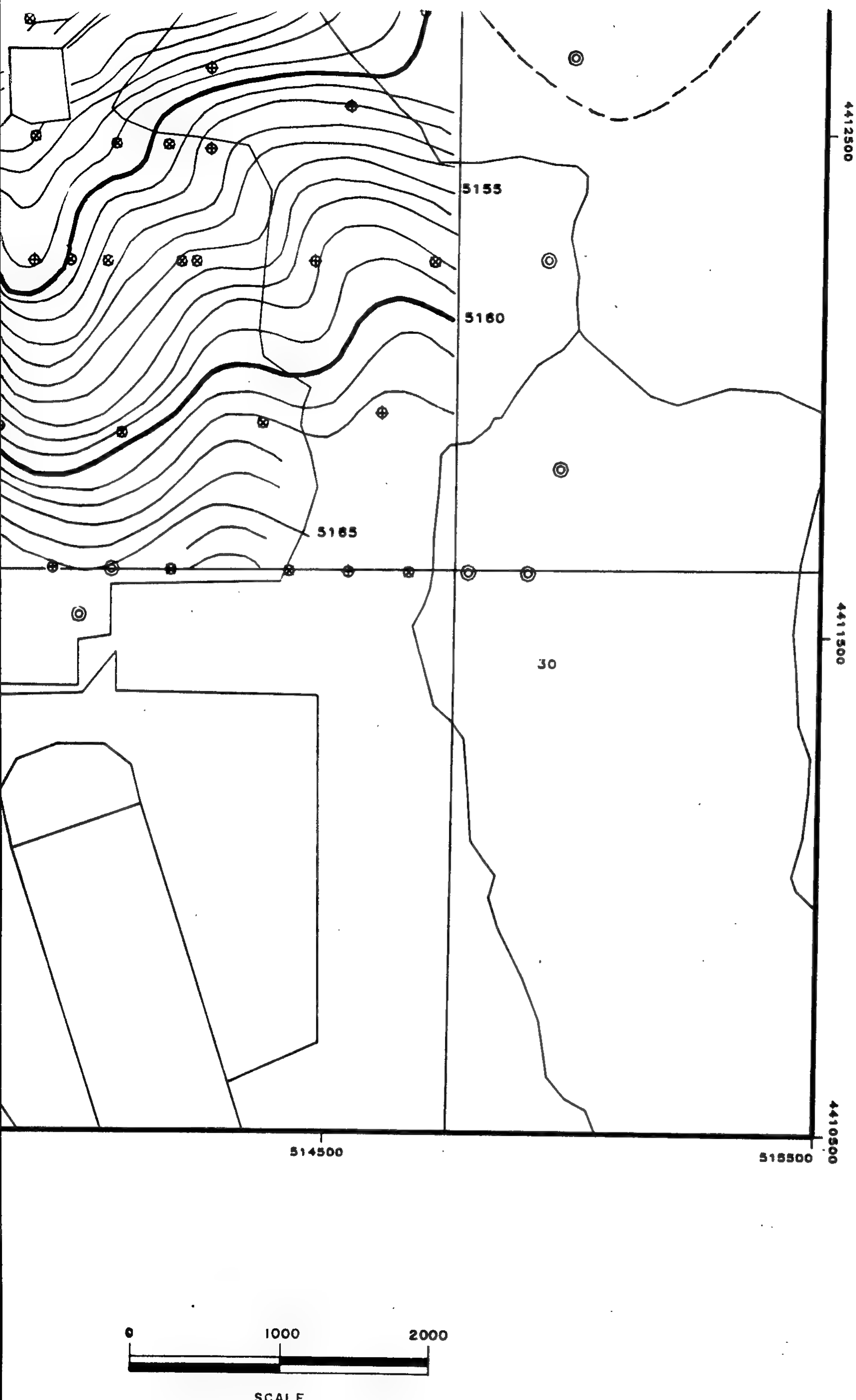

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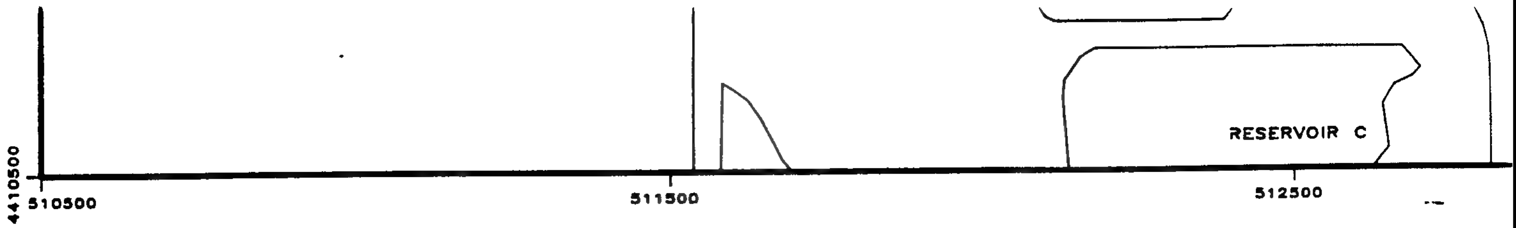

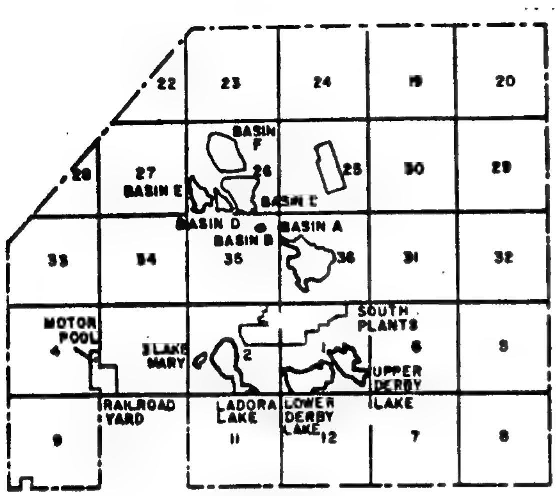

LOCATION MAP

LEGEND

- Injection Well
- Extraction Well
- Task 25 Sampling Well
- Task 25 Water Level Well
- Task 4 Sampling Well
- Task 4 Water Level Well
- Slurry Wall
- Areas Where Alluvium Is Generally Found To Be Dry

Figure 1.2-4
NORTH BOUNDARY CONTAINMENT SYSTEM ALLUVIAL WATER TABLE MAP
SOURCE: ESE, 1986

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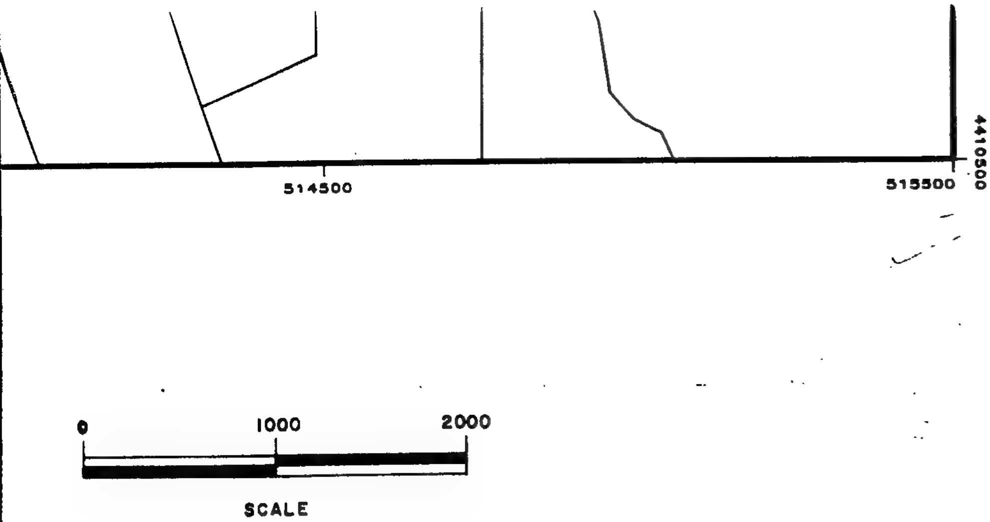

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

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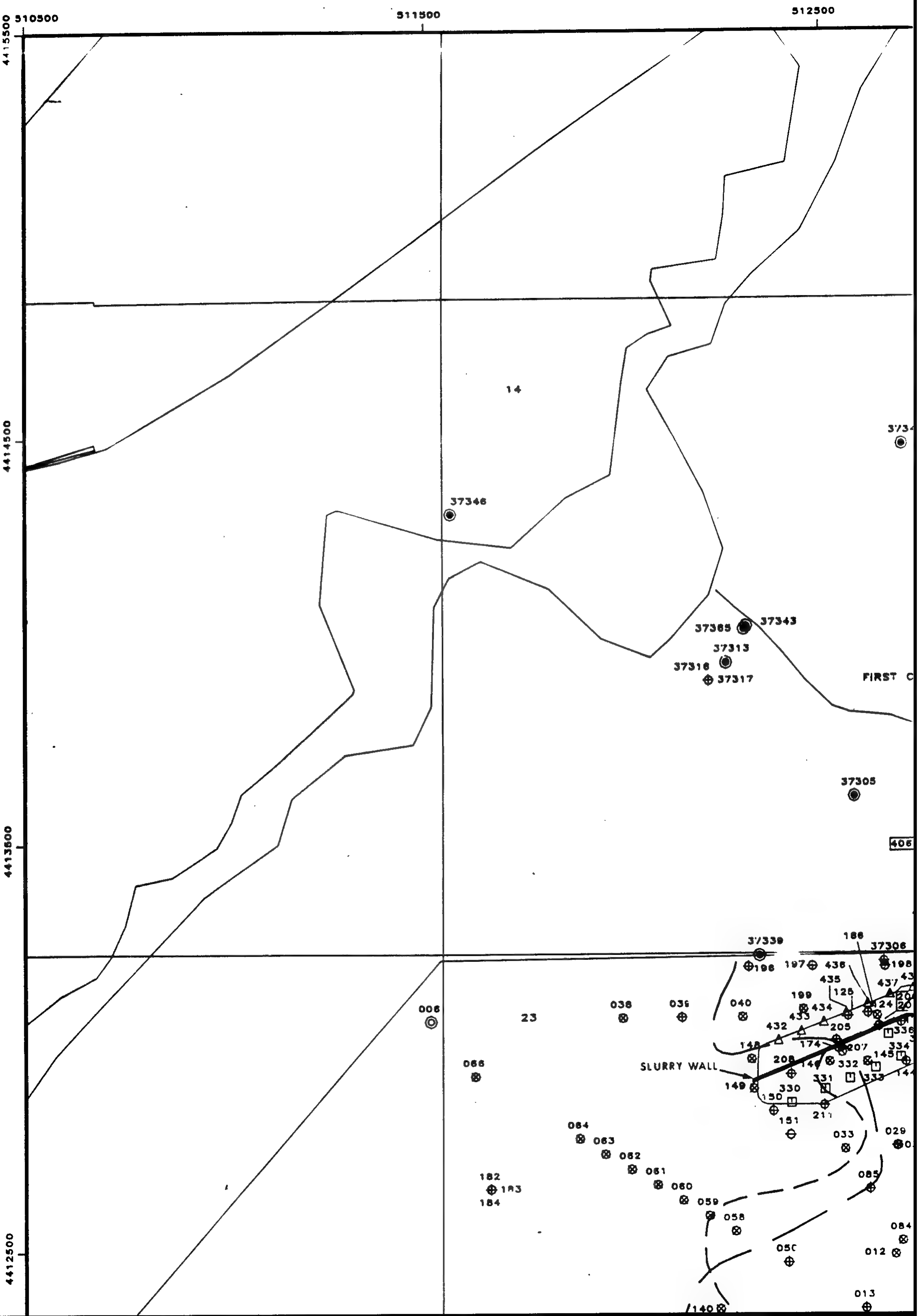

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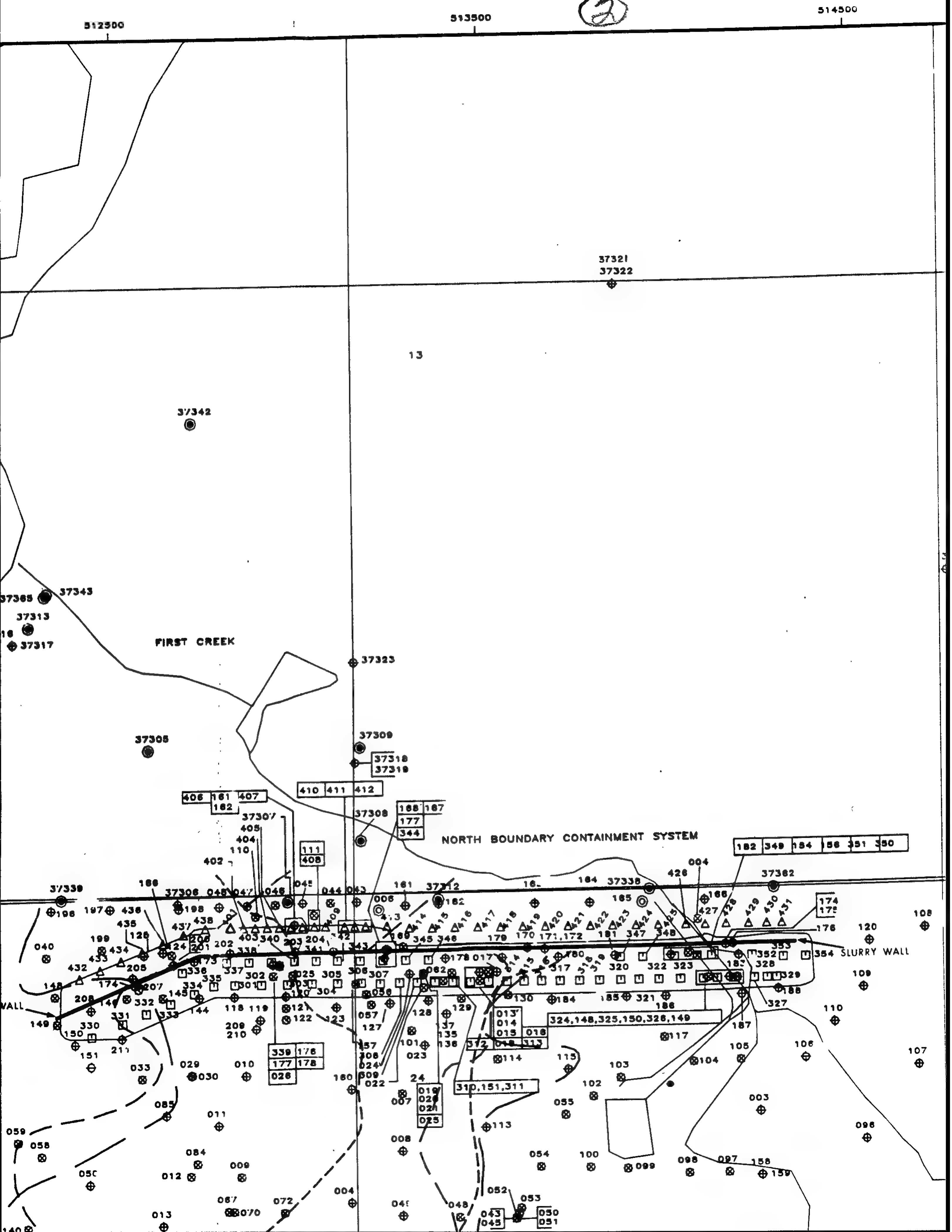
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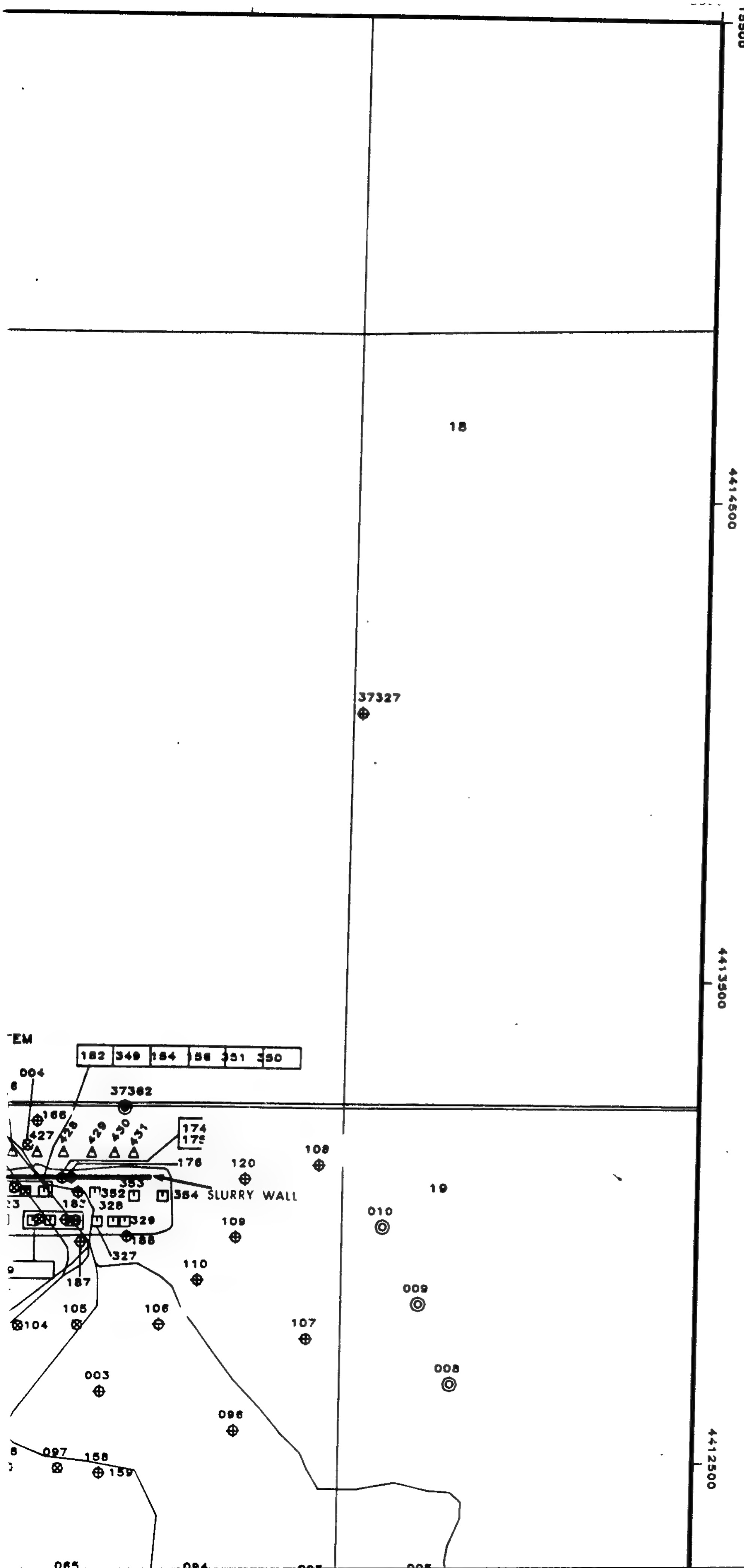

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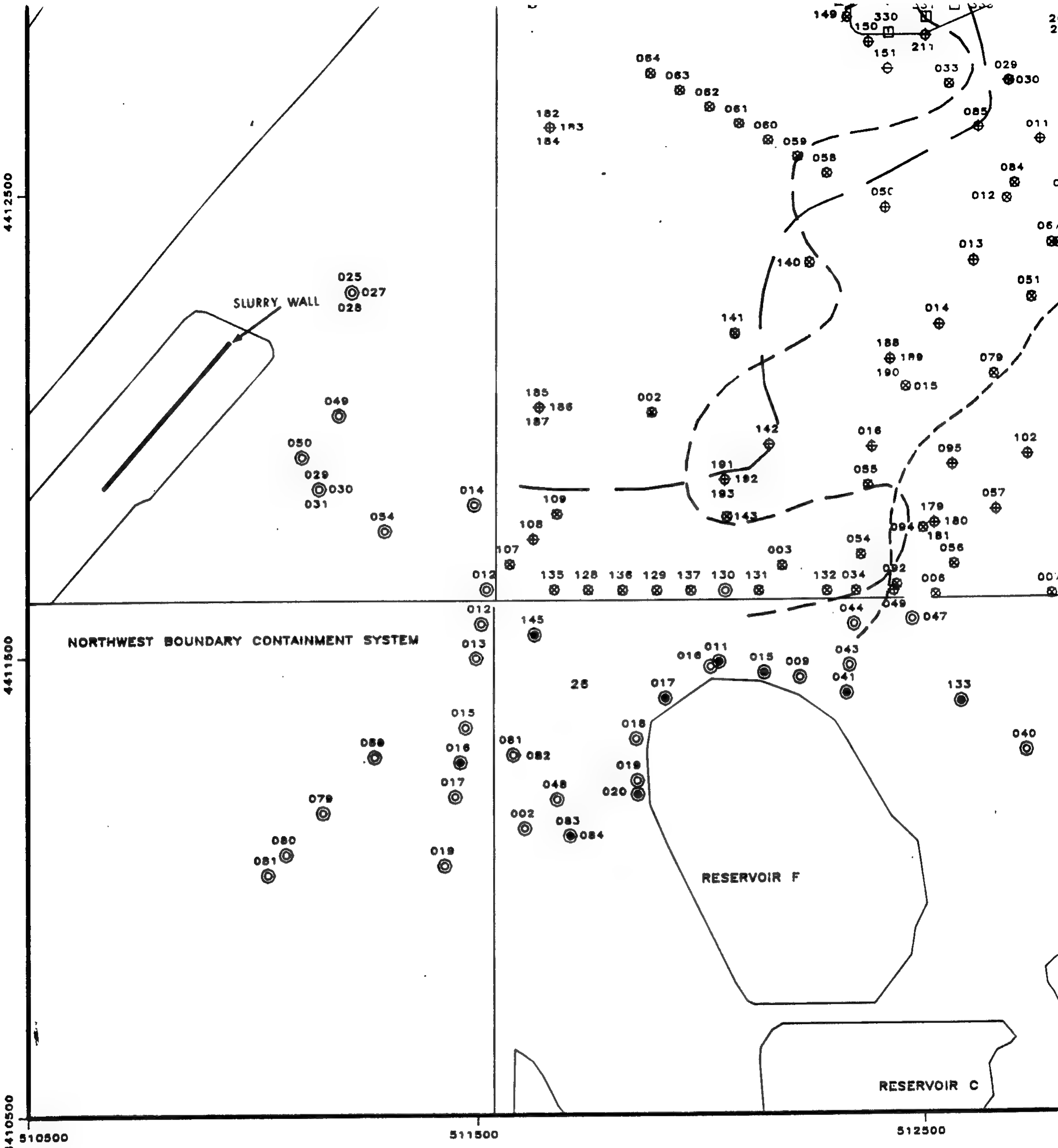
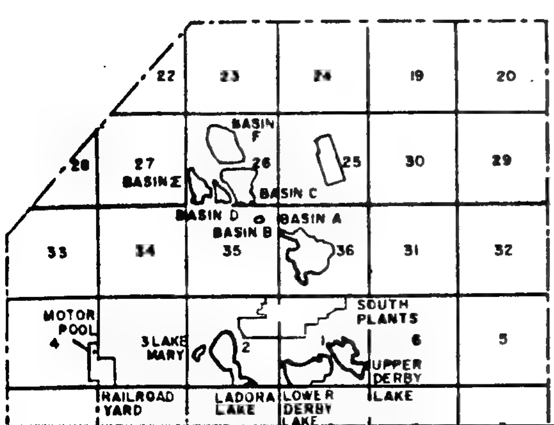




LEGEND

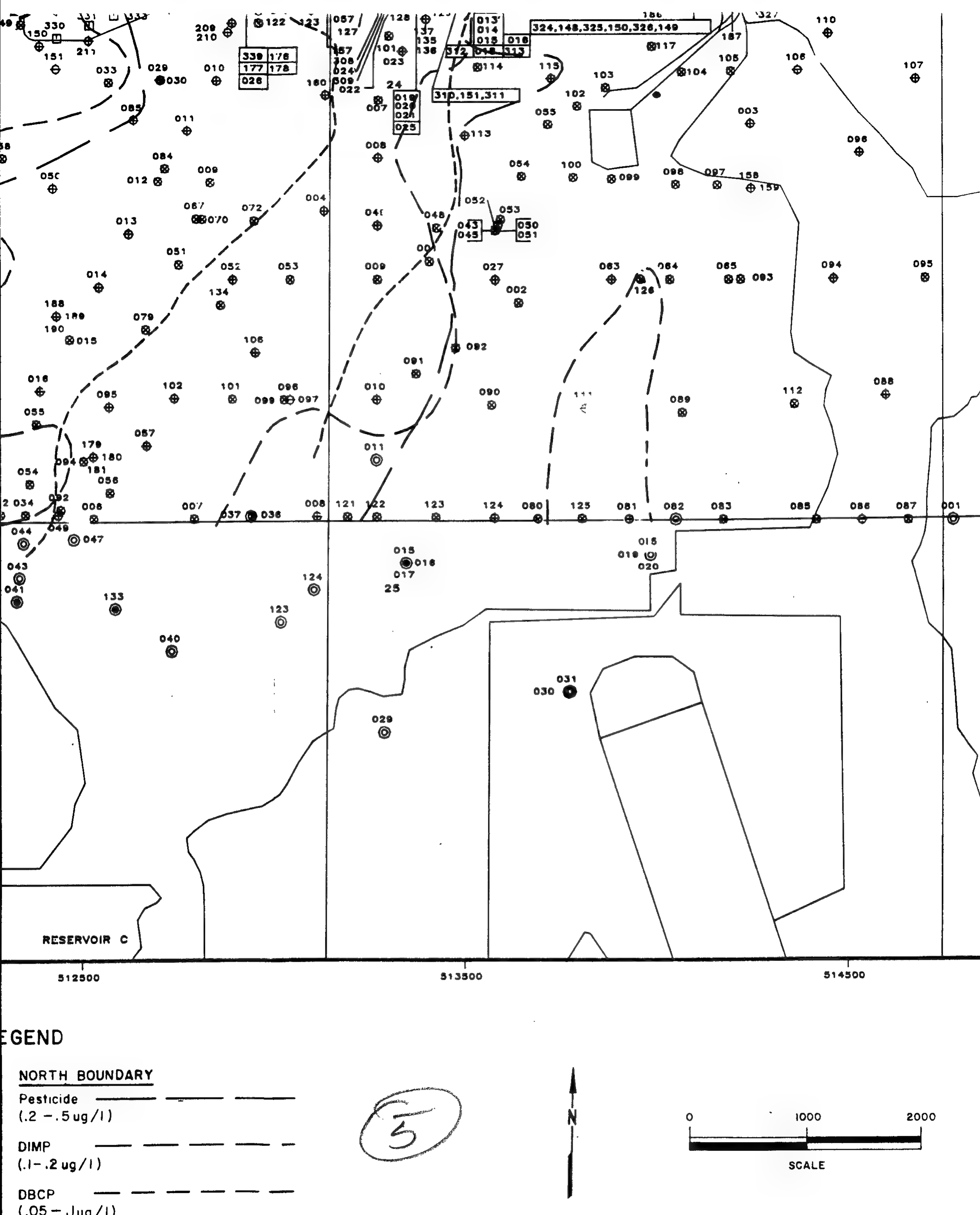
- Recharge Well
- Dewatering Well
- Task 25 Sampling Well
- Task 25 Water Level Well
- Task 4 Sampling Well
- Task 4 Water Level Well
- Slurry Wall

NORTH BOUNDARY

Pesticide (.2 –.5 ug/l)

DIMP (.1–.2 ug/l)

DBCP (.05 –.1ug/l)



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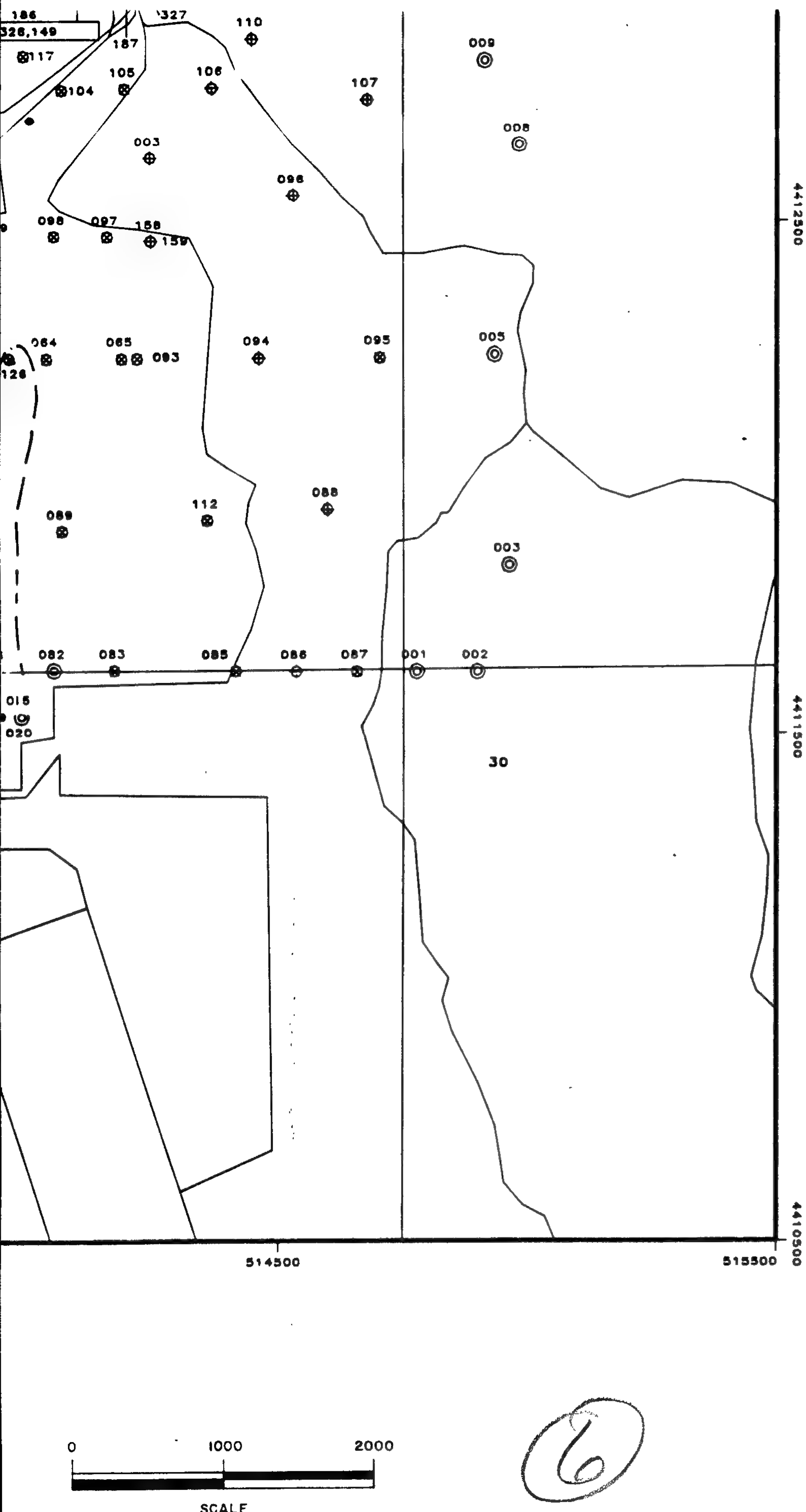
Pesticide
(.2 -.5 ug/l)
DIMP
(.1-.2 ug/l)
DBCP
(.05 - .1ug/l)
N
0
1000
2000
SCALE

5


186
328,149
327
110
187
117
105
106
104
107
009
003
008
096
098
097
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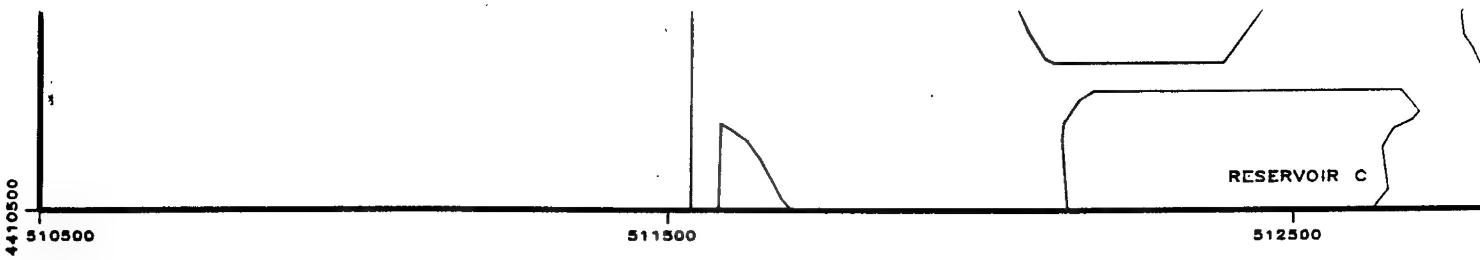
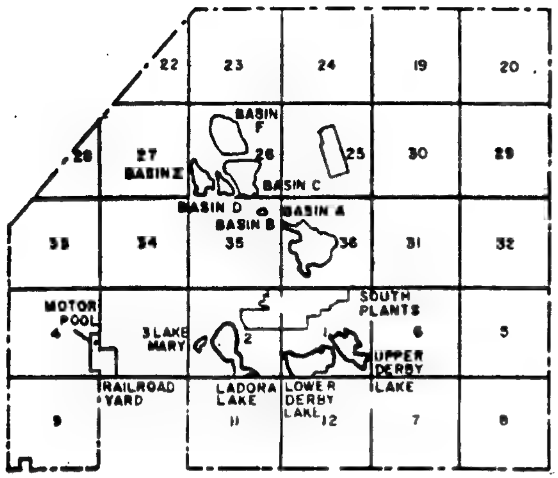
064
065
093
094
095
005
126
112
088
089
003
082
083
085
086
087
001
002
015
020
30
4412500
4411500
4410500
514500
515500
0
1000
2000
SCALE

6





LOCATION MAP

LEGEND

- Recharge Well
- Dewatering Well
- Task 25 Sampling Well
- Task 25 Water Level Well
- Task 4 Sampling Well
- Task 4 Water Level Well
- Slurry Wall

NORTH BOUNDARY

Pesticide (.2 –.5 ug/l)

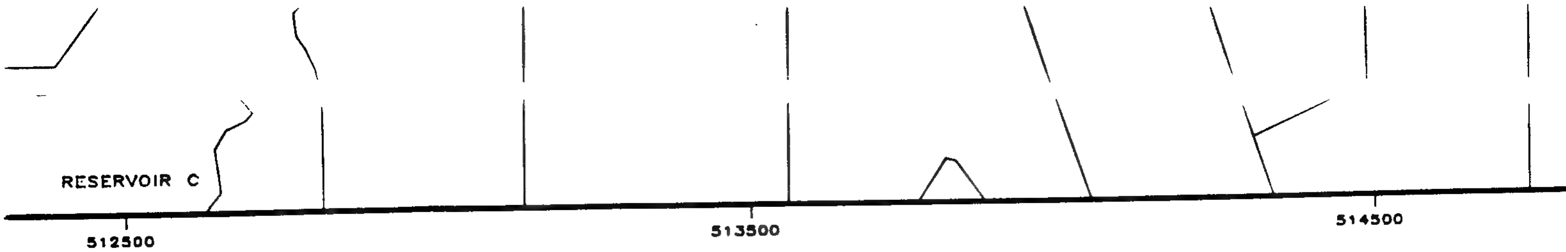
DIMP (.1–.2 ug/l)

DBCP (.05 –.1ug/l)

Figure 3.1-1
NORTH BOUNDARY CONTAINMENT SYSTEM MONITOR NETWORK WITH PLUMES

SOURCE: ESE, 1986

9



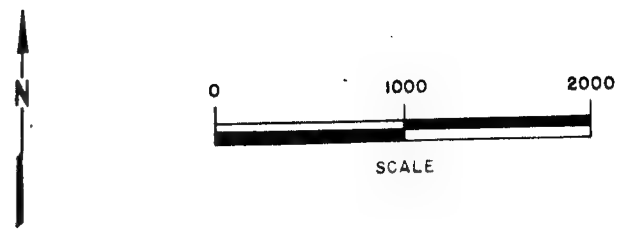
GEND

NORTH BOUNDARY

Pesticide
(.2 -.5 ug/l)

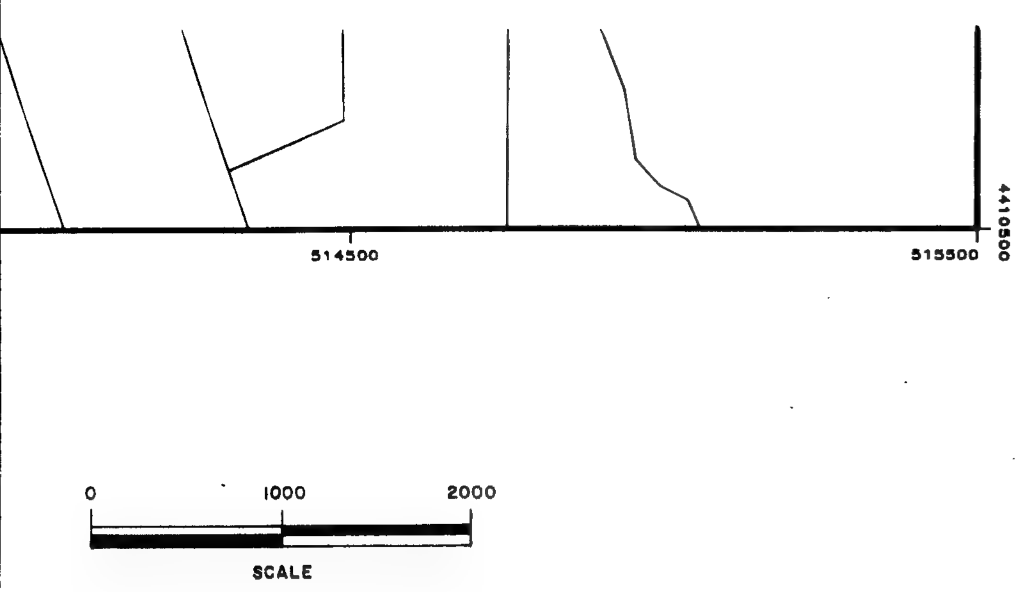
DIMP
(.1-.2 ug/l)

DBCP
(.05-.1ug/l)



H PLUMES

8



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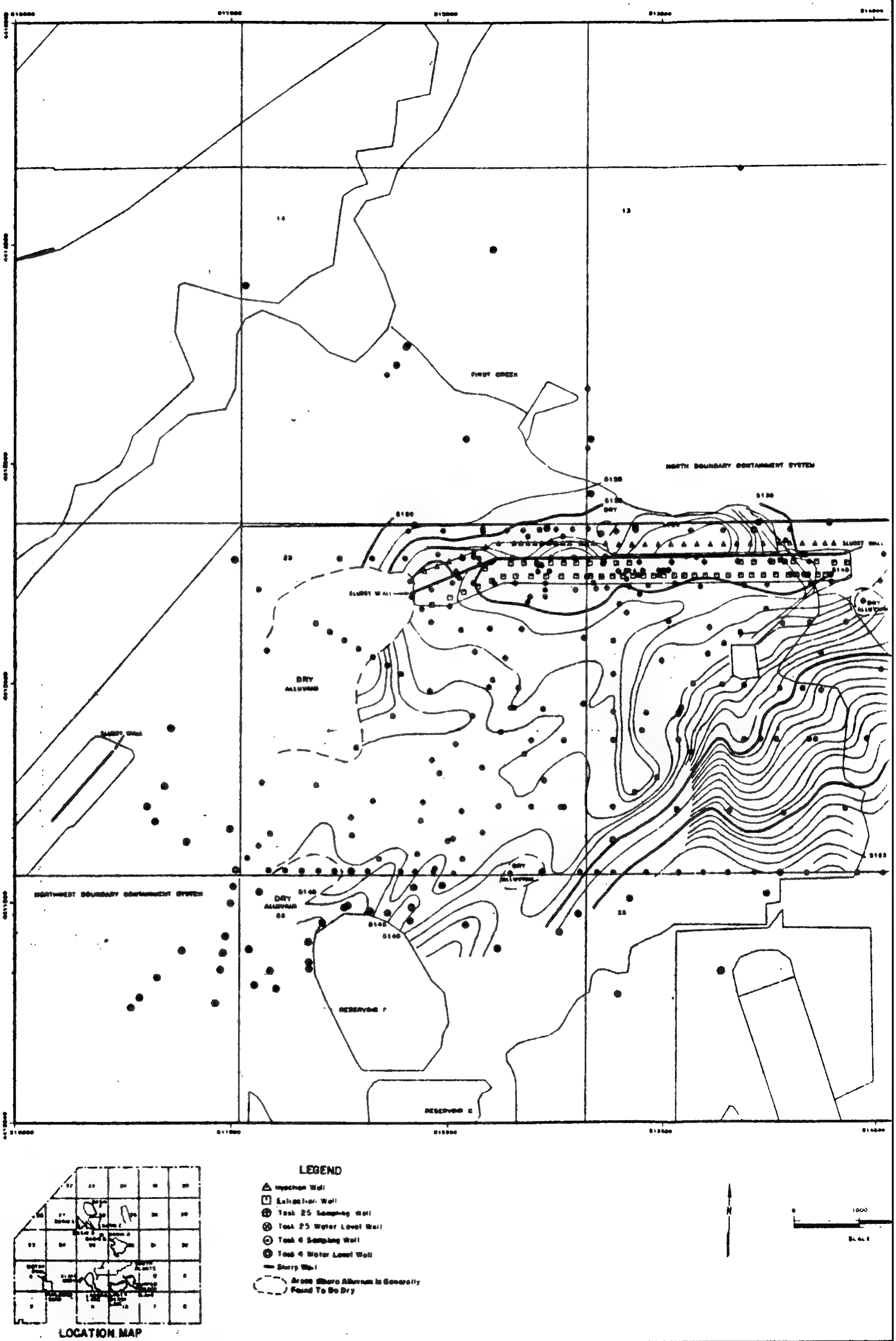
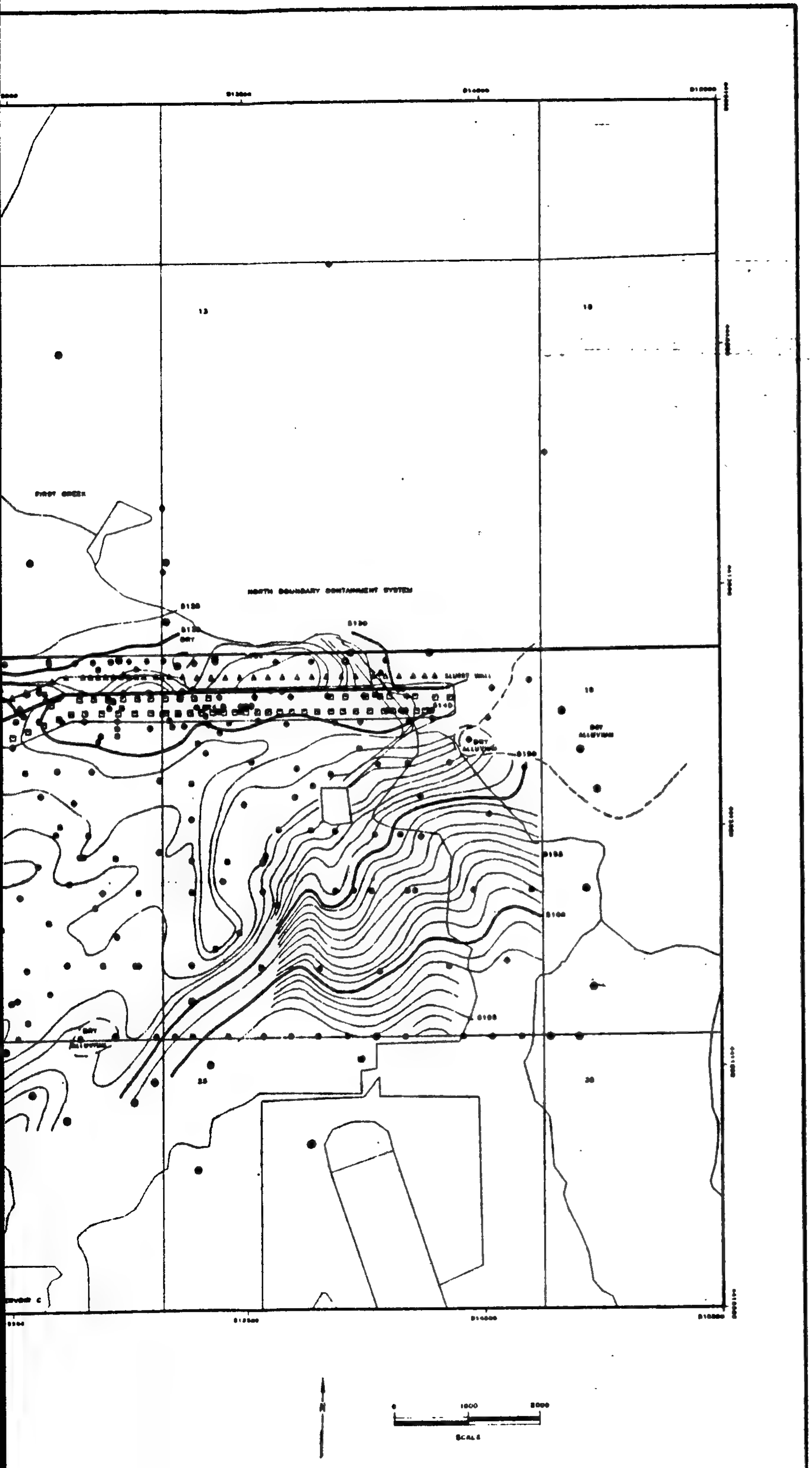
9


FIRST CREEK
NORTH BOUNDARY CONTAINMENT SYSTEM
SLUDGE WALL
DRY ALLUVIUM
NORTHWEST BOUNDARY CONTAINMENT SYSTEM
RESERVOIR F
RESERVOIR C
LEGEND
Injection Well
Extraction Well
Task 25 Sampling Well
Task 25 Water Level Well
Task 4 Sampling Well
Task 4 Water Level Well
Slurry Wall
Areas Where Alluvium Is Generally Found To Be Dry
N
SCALE
LOCATION MAP

1


FIRST CREEK
NORTH BOUNDARY CONTAINMENT SYSTEM
SLURRY WALL
DRY ALLUVIUM
DRY ALLUVIUM
DRY ALLUVIUM
5130
5130
5150
5165
0 1000 2000
SCALE

2

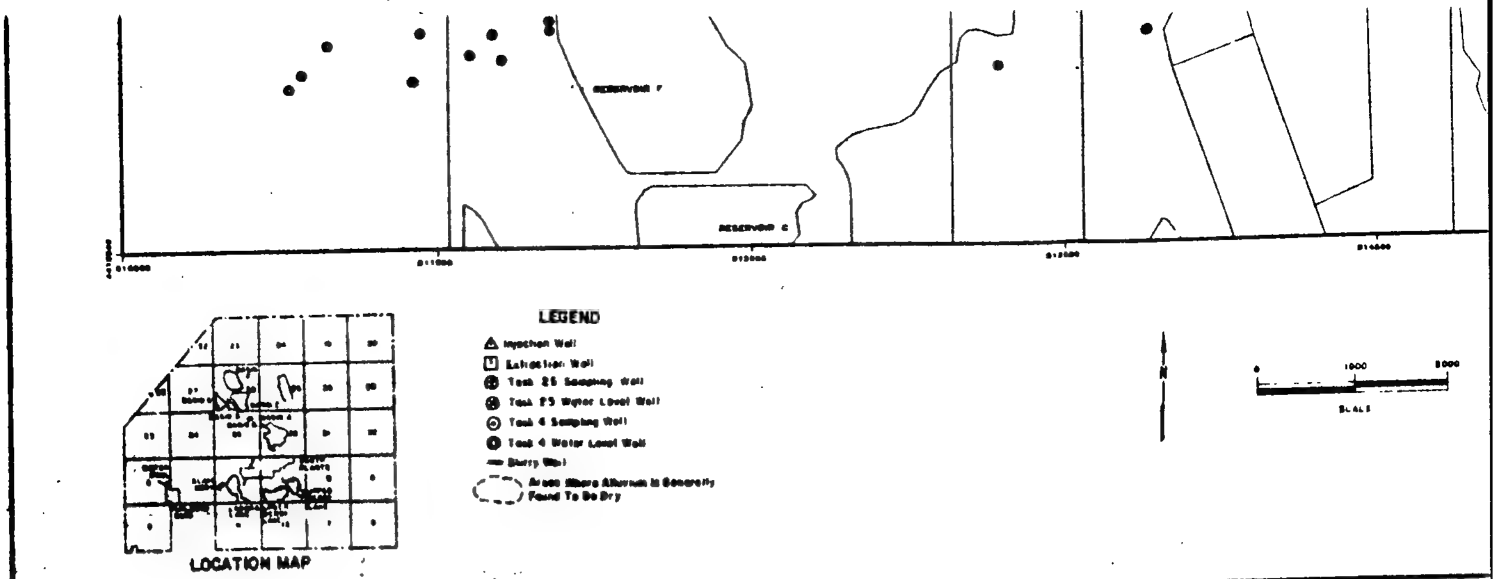
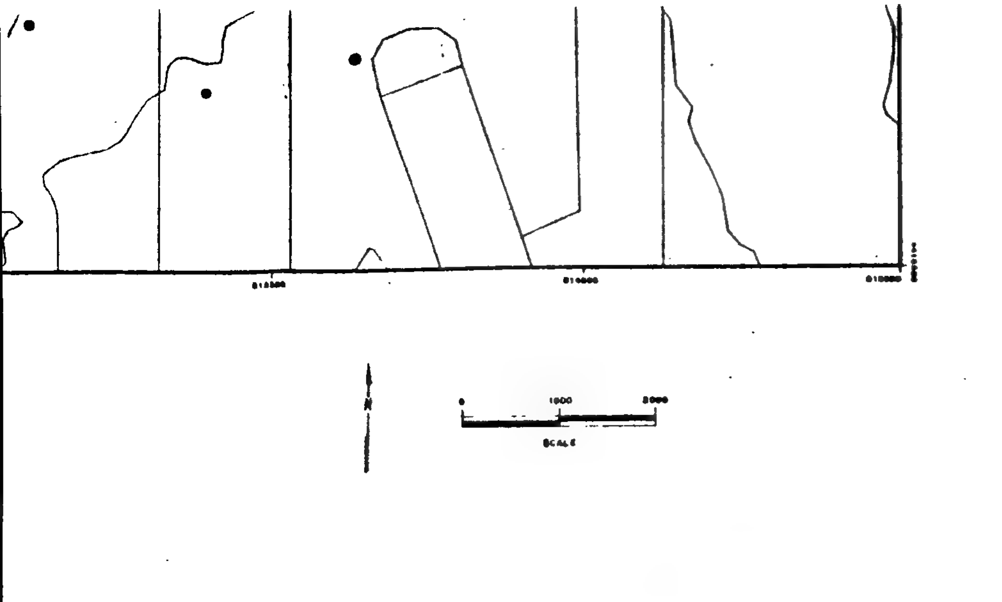


Figure 1.2-4
NORTH BOUNDARY CONTAINMENT SYSTEM ALLUVIAL WATER TABLE MAP
SOURCE: ESE, 1988

3



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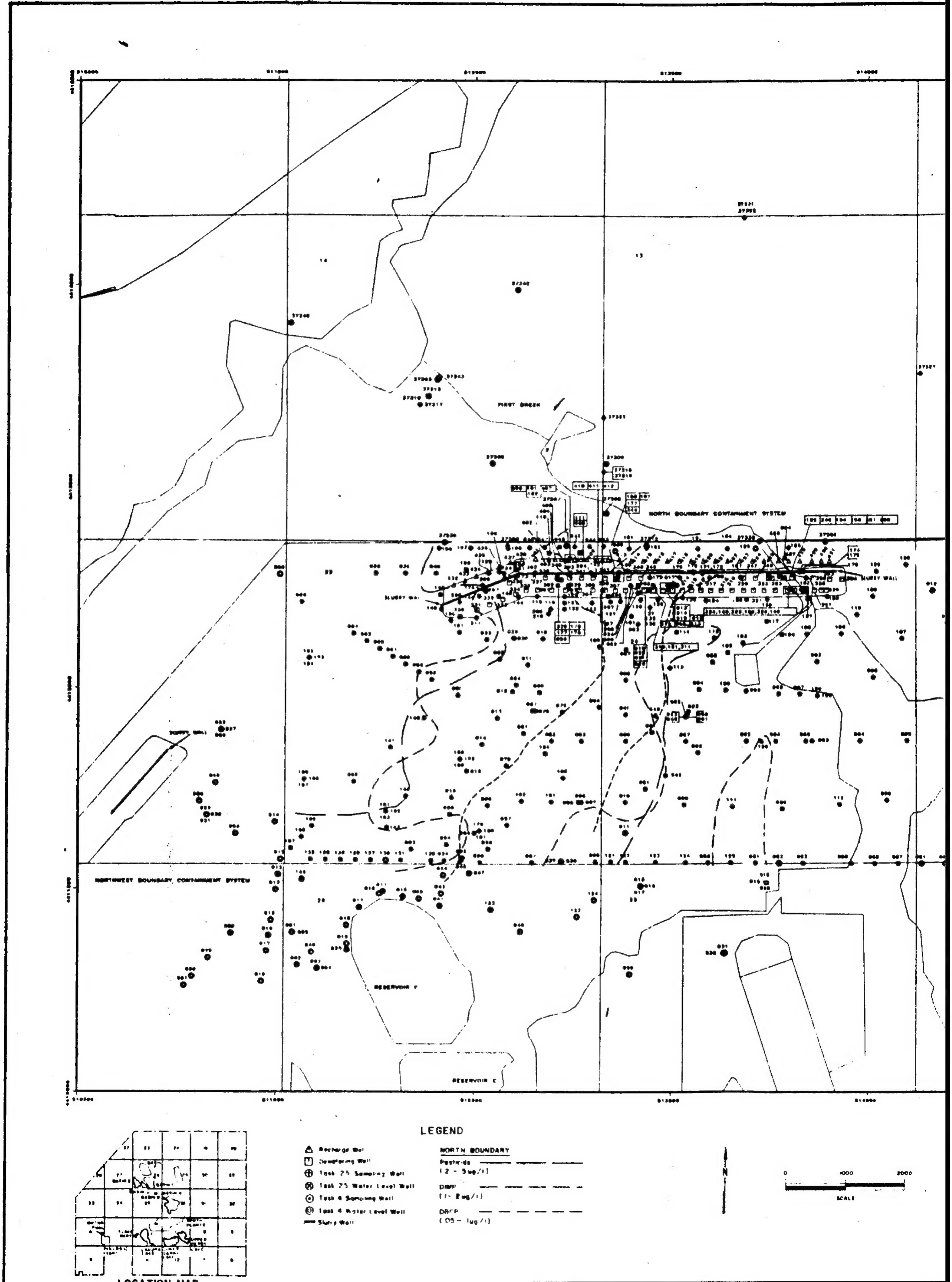
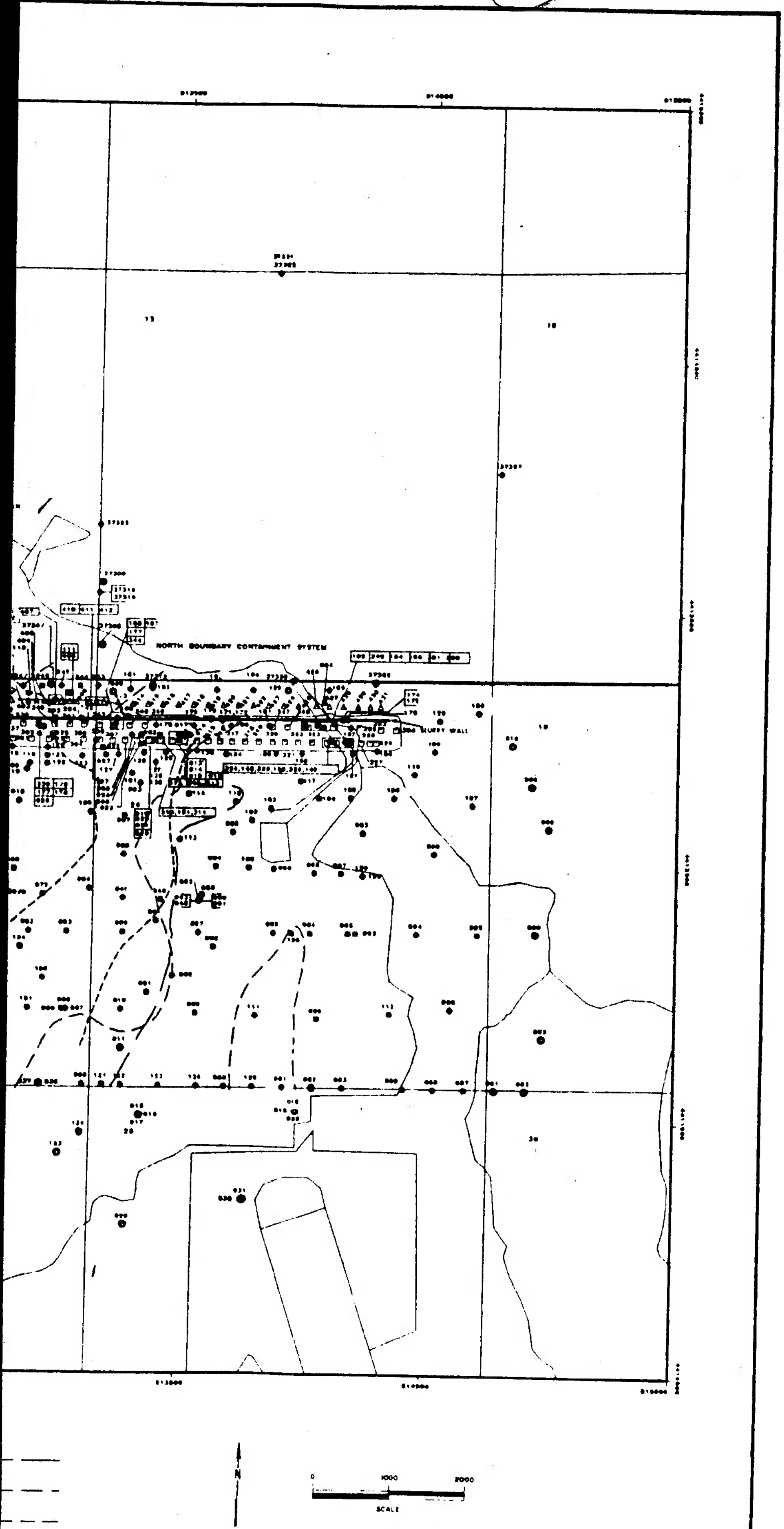
4

1


FIRST CREEK
NORTH BOUNDARY CONTAINMENT SYSTEM
NORTHWEST BOUNDARY CONTAINMENT SYSTEM
SLURRY WALL
RESERVOIR F
RESERVOIR C
LEGEND
Recharge Well
Dewatering Well
Task 25 Sampling Well
Task 25 Water Level Well
Task 4 Sampling Well
Task 4 Water Level Well
Slurry Wall
NORTH BOUNDARY
Pesticide
(2 - 5ug/l)
DIMP
(1- 2ug/l)
DBCP
(.05 - 1ug/l)
N
0
1000
2000
SCALE
LOCATION MAP

2



NORTH BOUNDARY CONTAINMENT SYSTEM
SLURRY WALL
N
0
1000
2000
SCALE

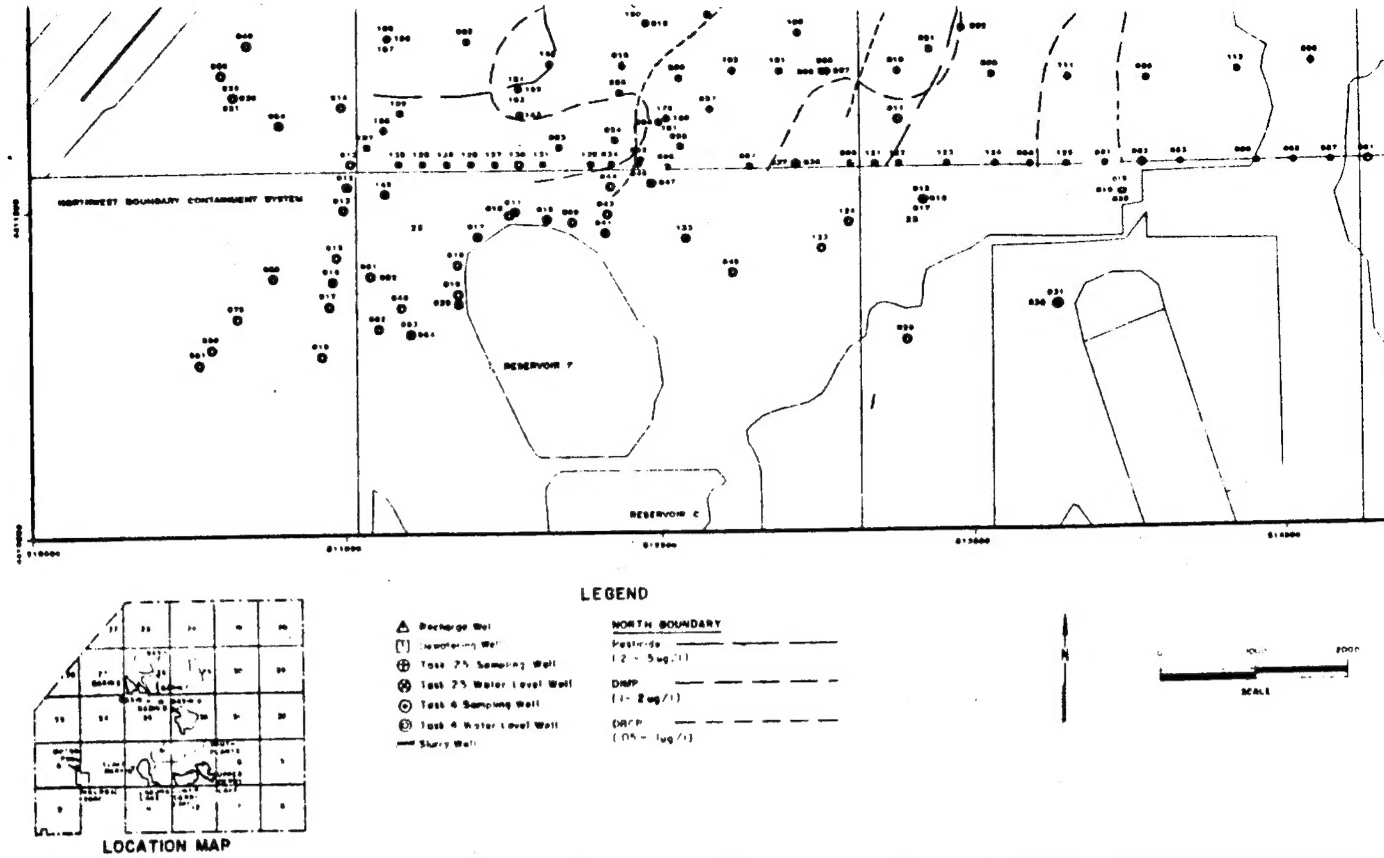
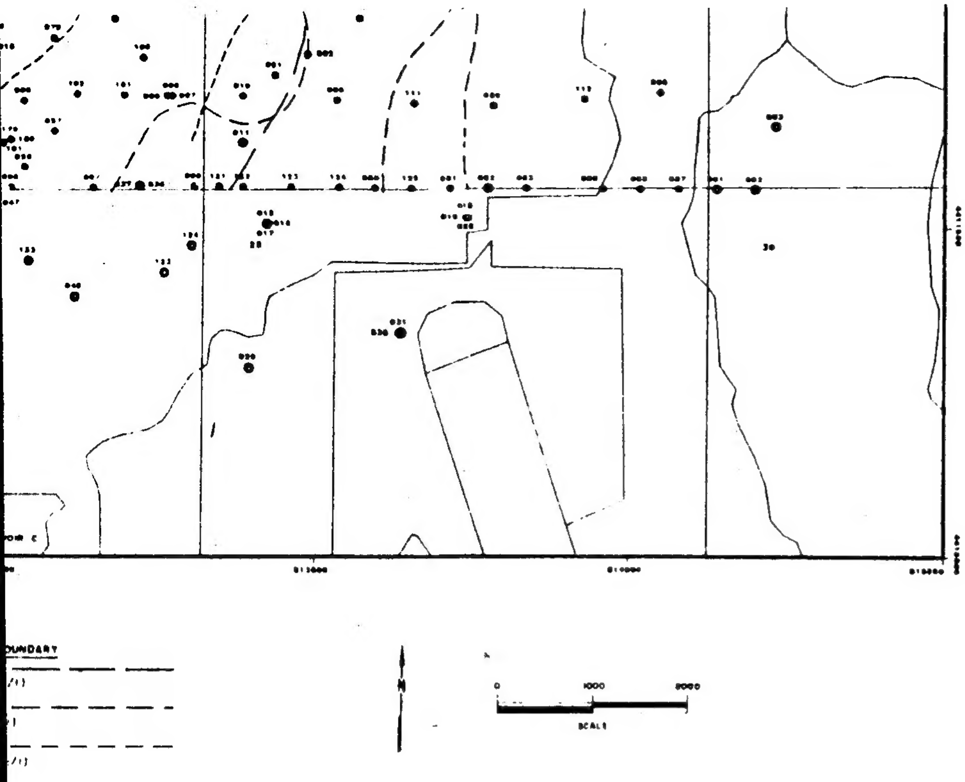


Figure 3.1-1
NORTH BOUNDARY CONTAINMENT SYSTEM MONITOR NETWORK WITH PLUMES

SOURCE: ESE, 1986

3



S

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